The determinants of environmental policy and diplomacy

An empirical investigation of participation in environmental treaties and the influence of domestic pressure groups

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Abstract

Why do countries join environmental agreements? What determines the success or failure of an environmental agreement? In this thesis we look at the determinants of participation in environmental agreements, paying special attention to the role played by domestic interest groups and the quality of institutions. To answer our research questions, we assembled the largest participation data set in the literature. This data set contains both global and regional agreements. Unlike previous data sets, it identifies the potential members of every treaty. This allows us to correct the identification bias subsisting in previous works. In this thesis we use a multilevel survival model to study the determinants of participation in environmental agreements. Our methodological approach introduces a number of improvements over previous empirical works, in particular with reference to the treatment of unobserved heterogeneity. It is also the first time a Bayesian technique (MCMC) is used in the estimation of participation models.

We expand the traditional framework of analysis with a study of the implementation stage of treaties. In this respect, we study five different variables that capture how a country fares in terms of environmental policies. It is the first time a study of participation is conducted jointly with the analysis of domestic policies. This framework yields interesting conclusions on the determinants of international cooperation and their final impact on environmental commitments. 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. We reveal that similar results for industrial lobbying had been obtained in previous empirical studies. However, this relationship has never been investigated in detail.

We advance an explanation based on the lobbying preferences of environmental and industrial interest groups. The explanation is tested on domestic policies; the results show that a dichotomy exists in the way environmental and industrial pressure is exerted. Environmental influence focuses on treaty participation choices and other normative governmental measures. On the contrary, industrial lobbies prefer to target the implementation stage of environmental agreements, especially the measures that are more rewarding in economic terms. We also find evidence that institutions play a vital role in fostering participation in environmental agreements, and that interest groups tend to be more influential when the quality of institutions is lower.

The study draws a number of policy suggestions. We stress the capacity of regional agreements to deliver higher participation rates than global agreements. We also highlight the importance of securing the participation of key players in the initial years to promote adherence to the agreement. Finally, we illustrate how our model can be used to generate probabilities of joining environmental agreements. The content of this thesis is relevant to treaty negotiators and any entity that has an economic or private interest in environmental agreements.

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Declaration & Copyright

I confirm that no part of the material presented in this thesis has previously been submitted for a degree in this or any other university. In all cases the work of others has been fully acknowledged.

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F.S.B.

Dedicated to my grandmothers, nonna Iole and Simonetta, who passed away before the completion of this thesis

Chapter 1

Introduction

It is apparent that international cooperation will soon be required to solve some of the most serious environmental problems of our times. Air pollution, contamination of lakes and rivers, global warming, biodiversity loss, deforestation, desertification, or overfishing are all problems that cross national borders and very seldom impact only one nation. Environmental agreements are the primary instrument to address these types of issues. To date we count more than 3000 environmental agreements[1]. However, our current knowledge on the dynamics surrounding international cooperation is limited. Why — despite the costs associated with agreements — do sovereign nations voluntarily decide to participate in environmental agreements and abide by their terms? Why do some agreements succeed and others fail? Why do some countries participate in more agreements than others? Is there any factor at the national level that systematically enhance participation rates? If so, how can policy makers intervene to improve the likelihood of solving transboundary and global environmental issues?

This thesis tackles a question which is at the core of the international governance of the sustainability debate. We investigate the drivers behind countries decision to join environmental agreements. Environmental economists have treated the subject chiefly from a game theoretical perspective, focusing on the formation and the stability of international coalitions. In this thesis, we employ a different approach. We conduct an empirical investigation of the factors affecting particip-

[1]Mitchell (2017) identifies around 3300 environmental agreements. This number includes both bilateral and multilateral agreements.

ation in environmental agreements and test some of the main hypotheses of the economic literature. In order to conduct this analysis a purpose-built data set has been collated from several sources.

This data shows that there is a considerable difference among countries in terms of participation in environmental agreements. Figure 1.1 shows that these differences are not random, rather, they seem to be clustered geographically, suggesting that a number of geo-economic factors are at play. The scope of our analysis is to gain a better understanding of the determinants of participation choices. More specifically, our research focuses on the effect exerted by domestic pressure groups on countries choice to participate in environmental agreements and explore the role that institutions play in this relationship.

The remaining part of this chapter provides some background information on environmental agreements, explains how they are formed and introduces some terminology linked to international treaties. The last section outlines the structure of the thesis.

What is an environmental agreement?

International environmental agreements are accords between international entities, such as governments, with the objective of regulating matters related to the environment. Very often, in the field of environmental economics they are referred to as international environmental agreements (IEA) or multilateral environmental agreements (MEA). For clarity, the use of acronyms is minimised in this work, we will prefer the nomenclature "environmental agreements" or "environmental treaties". Also, for convenience, we will often refer to international environmental agreements simply as "agreements" or "treaties". Unless stated otherwise, the term "agreement" or "treaty" is referring to an environmental agreement.

All multilateral agreements are governed by the principles of international law, and environmental agreements make no exception. In general, they involve a text that is negotiated and then separately and unilaterally approved by the international entities that are interested in participating. The power of an agreement is entirely based on the voluntary acceptance of its term by the individual countries. That is to say, the agreement is binding for the country only if the country accepts to be bound by the agreement. There is no superior force capable of coercing a country into compliance with the agreement except from its own voluntary participation in the agreement. As a result, the participation to a treaty is fundamental for the success of the treaty itself. The approval of an agreement is generally expressed in two stages:

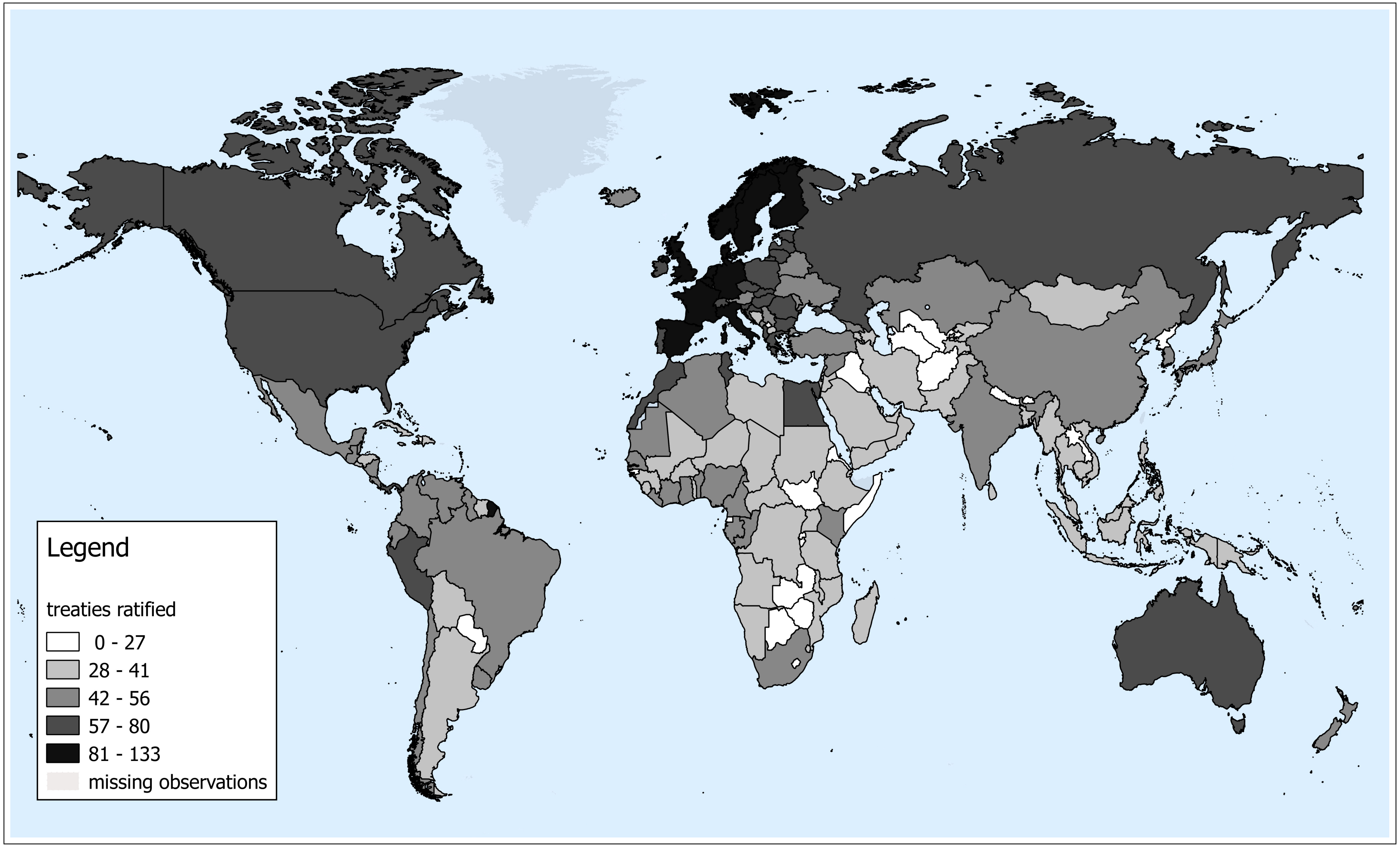

Figure 1.1: *Number of environmental treaties ratified*

Notes: The map shows the number of environmental treaties in the data set that have been ratified by the country in 2017. For more information on the ratification data refer to section 5.2.

first the *signature* and then the *ratification*. We will now provide an explanation of how this mechanism works.

How environmental treaties take shape

According to Barrett (1998) there are 5 stages in the formation of international environmental agreements: *i*) pre-negotiations, *ii*) negotiations, *iii*) ratification, *iv*) implementation, and *v*) renegotiations (amendments and changes to the treaty following ratification). The first two phases are conducted by national delegations. They culminate with the consensus over a text that is then signed by the participants to the negotiations. The signature signals approval of the agreement's content. Nonetheless, the treaty is not yet operational at this stage. After the signature by the executive power, the treaty needs to be ratified. Different countries have different procedures, but ratification is normally a prerogative of the legislative body and entails the adoption, at the national level, of the content of the international agreement. Ratification is fundamental because it formally transforms the content of the treaty into national law. The implementation of the treaty only starts after the act of ratification. In this study, we will focus on ratification because it is the legal act that renders the treaty operational.

In the course of our analysis, we use indiscriminately the term ratification to indicate both the act of ratification *sensu stricto* 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 to the negotiations. For the purpose of this study, the *ratifiers* of an agreement are the countries that submitted either an act of ratification or of accession to the agreement. The ratifiers are different from the signatories, because the latter term refers to the act of signature, while the former to that of ratification. The ratifiers are also called the *members* or *parties* to an agreement.

In this study we focus primarily on *ratification* because it is the only act that formally binds the nation. In fact, the signature of an environmental agreement signals willingness to cooperate, but it entails no obligations for the signatory nor does it force the country to ratify the agreement at a later point in time. For all these reasons, the act of signature is essentially costless. In the economic literature, the expression "participation" is the term most commonly used to express the decision to comply with the terms of the agreement. In this study, "participation" and "ratification" are used in the same way, however, whenever possible we prefer the term "ratification" because it is less vague and directly alludes to the ultimate act of participation in an environmental agreement.

Structure of the thesis

In the next chapter we present the goals of our research, outlining the main questions that we seek to answer and describing our main contributions to the economic literature. Chapter 3 is a comprehensive review of the empirical evidence on the determinants of ratification. Chapter 4 presents the theoretical framework of analysis, setting our research in the context of the existing theoretical literature. Moreover, we define the key hypotheses that are tested in the following chapters. Chapter 5 describes the methodological approach of this study, explaining and motivating both the modelling choices and the estimation technique. The second part of chapter 5 is dedicated to presenting the ratification data set and examining possible issues related to the data. The results of the analysis are reported and discussed in chapter 6 and 7. Finally, chapter 8 summarises the main conclusions and expounds on the policy implications and the main limitations of the empirical study.

Chapter 2

Research questions and motivation

The introduction chapter described how environmental agreements are formed and details the successive stages in treaty participation. In this section, we discuss how environmental problems that cross national borders differ from local environmental issues and explain why this type of problems calls for a different type of solution. Since traditional policy tools are ineffective in a multilateral setting, often, the only possible solution is to cooperate through environmental agreements. Therefore, environmental agreements are crucial to solve most of the large environmental issues of the 21^{st} century. In this section we also present our main research questions and explain how this thesis contributes to the existing literature on the participation in environmental agreements. The first part of the chapter stresses the importance of environmental agreements and links our work to the existing fields of research. The second part of the chapter highlights the key contributions of this thesis.

2.1 Scope and relevance of environmental agreements

This section expounds on the differences between local and transboundary environmental problems. We explain that the fundamental difference lies in the absence of a central authority, which ultimately makes traditional policy tools inapplicable. Transboundary environmental issues have to be resolved through international cooperation. This section describes the central paradigms of the literature on international agreements. Then, it introduces our research questions and discusses the focus of the analysis. The last paragraph of the section examines the relevance and implications of this research area.

2.1.1 Environmental problems and environmental policy tools

Most environmental issues are linked to a failure of the first fundamental welfare theorem. In fact, most environmental problems derive from externalities, missing markets or some form of non-rivalry and/or non-excludability in consumption. From a normative perspective, environmental economics proposes a number of different policy tools to correct market failures such as Pigouvian taxes, subsidies, cap and trade mechanisms or emission standards. All these measures imply the existence of a central authority capable of enforcing environmental policies.

Unfortunately, nature obeys no borders. An environmental problem can affect many countries, or even all countries, at the same time. In these cases, the enforcing power is missing and all the above mentioned measures are insufficient to correct the resource misallocations caused by the market failures. The conventional framework of analysis assumes a *vertical* system of laws whereby the policy maker possesses the authority to allocate property rights, impose taxes and enforce standards (Barrett, 2005). However, in transboundary environmental problems, there is no single dominating power that possess the coercive power needed to enforce environmental policies in all the countries concerned. This decentralisation calls for a *horizontal* approach based on cooperation (Barrett, 2005).

This question is of great relevance because a large number of environmental problems cross borders. If a company located in India releases hydrochlorofluorocarbons (HCFC), the resulting damage to the Ozone Layer is borne by the United States just as if the emission had originated on its soil. If a factory releases toxic wastes in large rivers, they may contaminate waters in all countries downstream. Chernobyl radioactive fallout was quickly dispersed all over Europe by winds. The methane released by thawing Siberian permafrost contributes to the heating of the entire atmosphere. The deforestation of the Amazon rainforest can be preempted by few countries alone, but any loss in biodiversity and forest area impact all nations on Earth. In all these examples, the impact of environmental damages affect multiple nations. Moreover, the country — or entity — responsible for the damage to the environment does not bear the full social cost associated with their actions. Foreign nations have no way of intervening and, in the case of shared resources, any measure taken unilaterally may be unable to solve the problem and is unlikely to take into account international externalities.

We have seen that many of the most pressing environmental problems often have transboundary impacts. If traditional policy tools fail, what are the solutions for this type of problems? The heart of the question lies in the absence of an international authority capable of enforcing decisions in all countries concerned. The simplest solution would be to merge all countries into a unique global state, then, the same type of policies would be applicable. However, this solution is highly implausible. Another option would be to bestow on a nation the absolute authority on environmental issues or to constitute a form of "world government" having the uncontested authority to enforce decisions. Both these options seem equally unlikely, countries are often averse to relinquishing their power and autonomy, and foreign interference is rarely accepted without resistance. As a result, the only viable solution is for countries to agree through negotiations on mutual and voluntary restraints. This solution takes the form of international environmental agreements and is the most effective tool currently at our disposal in a *horizontal* order (Barrett, 2005).

Environmental agreements are the primary tool for international cooperation on environmental issues. The good news is that — in theory — there is an incentive to cooperate because total welfare could be increased by tackling the environmental issue in a multilateral manner(Carraro & Siniscalco, 1998). Nevertheless, cooperation is not obvious because there are also incentives to free ride when no central authority is capable of enforcing an international agreement. That explains why the emphasis of the theoretical literature has been on the need for self-enforcing characteristics in the treaty (Barrett, 2008). Re-

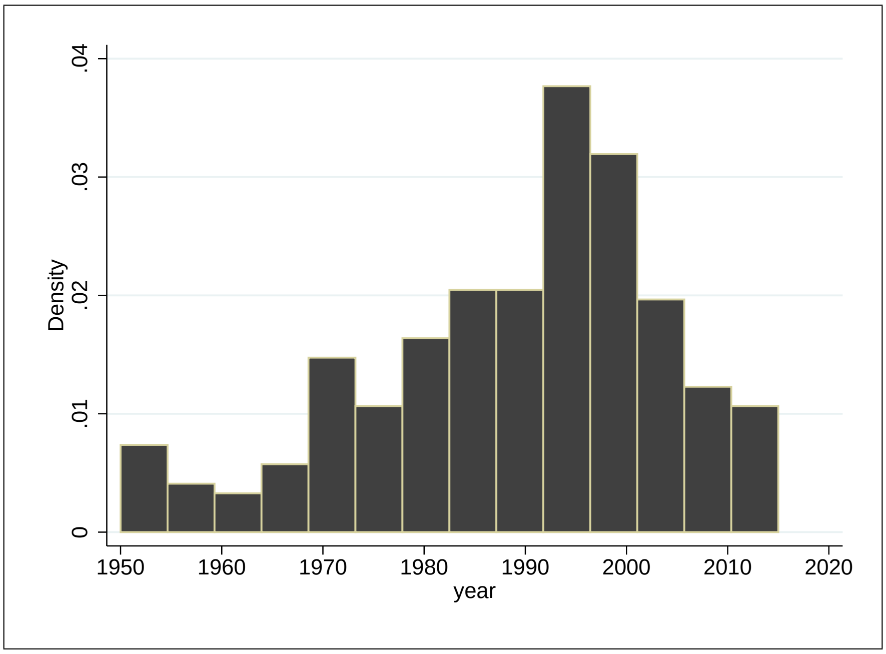

Figure 2.1: *Number of new agreements by year*

Notes: For details on the data and sources refer to section 5.2.

cent trends show that environmental diplomacy seems to have gained traction and multilateral environmental agreements are becoming an increasingly popular tool to solve environmental problems (figure 2.2). The end of the 20th century was a period of fertile and intense activity in environmental diplomacy. The progress in science led to a gradual surge in public awareness, ultimately prompting political action (Meyer et al., 1997). Figure 2.1 shows how the number of environmental agreements peaked in the 1980s and 1990s, which correspond to the establishment of the principal agreements and organisations dealing with the environment (Mitchell, 2003). At present, and in the near future, environmental policy and diplomacy will be a constant feature in government's agendas. For all of these reasons — and because the participation in environmental agreements is a quintessentially voluntary act — it is relevant and valuable to investigate the motivations that push countries to participate in environmental agreements. By studying the determinants of ratification, this study provides an evidence-based insight into the mechanics of environmental diplomacy and forges a better understanding of the tools available for solving transboundary environmental issues.

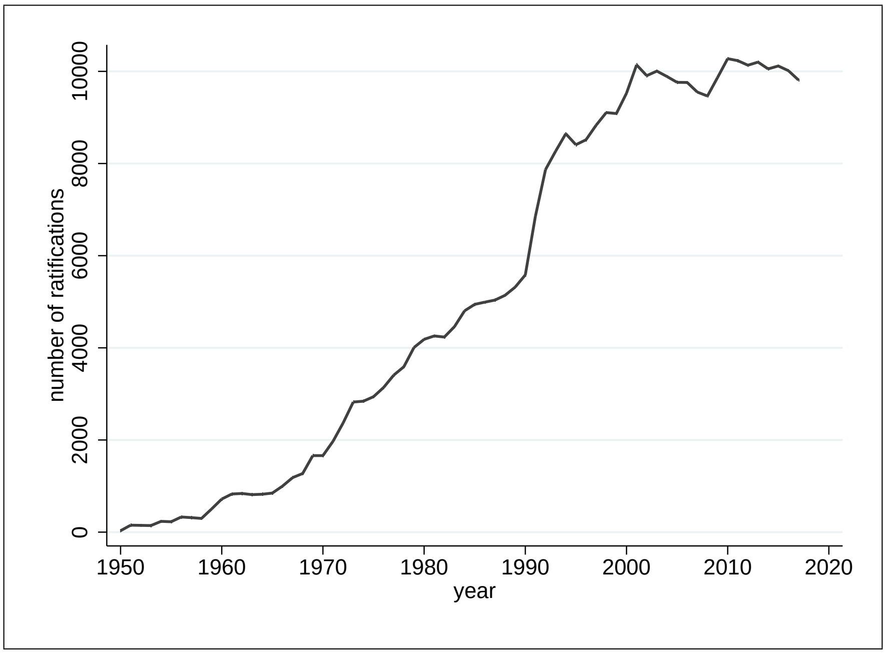

Figure 2.2: *Annual number of ratifications*

Notes: Ratifications refer to environmental agreements in out data set. Refer to section 5.2 for more information on the data.

2.1.2 Main research questions

The growth in global population and fast economic development will increasingly stress the natural resources and the global environment, affecting the quality — if not even the sustainability — of life on Earth. As a result, environmental issues will inevitably be a major concern for decades to come. In this context, international agreements are the leading tool in solving problems that cross national borders and affect several nations at the same time. With this in mind, we aim at providing a better understanding of the forces that drive international cooperation on environmental issues, hoping to create knowledge that could be useful to frame more effective environmental treaties in terms of participation and objectives. In particular, our research focuses on the following questions:

> Do domestic pressure groups influence the ratification of environmental agreements? And how is this relationship affected by the quality of institutions? Are good institutions facilitating international cooperation?

The decision to join an agreement is divided in two phases: signature and ratification. The reason why we study ratification is because it is the final and definitive act marking participation in the agreement. If the treaty does not correspond to the view or position of the country it should not, in principle, sign the agreement, because signature signals the will to abide by the treaty. However, we remark that such a signature is costless because it does not really entail any formal commitment to ratify and does not legally bind the country to environmental actions. At the same time, there is a dichotomy between the national bodies that have the mandate to negotiate and sign — normally the government — and the one that have the power to ratify — normally the legislative body. As a consequence, the set of motivations that drive signature and ratification may very well be significantly different. There is no reason why a country should behave as a monolithic bloc when decisions depend on different internal bodies. Moreover, a country that signed an agreement has no obligation to ratify, hence, signature does not necessarily lead to the implementation of the agreement. In conclusion, we prefer to look at ratification because signature does not formally create obligations for the country. Ratification is the legal act that truly marks the acceptance of the treaty.

In the traditional framework of theoretical analysis, ratification decisions are made by a unitary welfare maximising entity. However, in reality, they are the result of conflicting interests within the country. For this reason, it makes sense to analyse ratification as the outcome of two opposing tensions within the country: the so called *environmental* and *industrial* lobbying. These two forces apply opposing pressure on the decision to participate in environmental agreements. This framework echoes the recent developments in the economic literature; in recent years there was an attempt to integrate the public choice approach with the existing literature on participation in environmental agreements (e.g. Marchiori et al. 2017, Habla & Winkler 2013, Köke & Lange 2017 and Lui 2018). This body of literature formulates a number of predictions that we empirically test on how domestic pressure groups impact participation in environmental agreements. As of now, a comprehensive study of ratification and domestic pressure dynamics based on a large sample of treaties and countries is missing. Our aim is to fill this gap. Economic literature on participation in environmental agreements is mainly based on game-theoretical models (Finus et al., 2017). Our scope is to improve the understanding of ratification and collect empirical evidence, so as to test the predictions of this branch of economic literature.

In addition to environmental and industrial lobbying, we also investigate the role played by institutions in the cooperation over environmental issues. Institutions are defined as the legal and social constraints that structure the interactions between economic agents (Acemoglu et al., 2005). They set the operational rules and shape the incentives of agents, affecting the economic and social outcomes at different levels. The rule of law, political system, economic regulations, social norms, bureaucracy and the administrative apparatus, are all elements of institutions. Our notion of quality of institutions is centred upon the concepts of corruption, transparency and the effectiveness of bureaucracy. These aspects are directly related to the success of certain practices of lobbying. There are different ways interest groups can influence the decision to ratify international agreements. These include, lobbying via political channels, the formation of civil society groups, the provision of technical assistance, influencing public opinion, giving economic support, creating personal networks, influencing legislators and negotiators, or even bribery and other illicit means. Institutions and interest groups are intricately related when it comes to affecting international cooperation because any action aimed at international agreements inevitably passes through institutions. As a consequence, it makes sense to study institutions along side domestic interest groups.

In summary, the goal of this study is to understand the determinants influencing the ratification of environmental agreements. In particular, we focus on the action of domestic interest groups and on their effects interact with the quality of institutions. In this thesis, environmental lobbying refers to all the direct and indirect pressure exerted on policymakers aimed at promoting participation in environmental agreements. Unlike in other studies (e.g. Besley & Coate 2001 or Felli & Merlo 2007), lobbying refers to the global influencing activity and does not distinguish between pressure exerted through political representations (direct voting, election of representative, etc...) and civil society pressure (NGOs, demonstrations, lobbies, etc...). In addition, This thesis does not consider the negotiation phase of agreements. That is to say, we exclusively focus on the decision to ratify treaties that have been agreed, and do not investigate whether or not a treaty is negotiated on a given issue between certain countries. For the second type of analysis the counterfactual is missing: one cannot observe the treaties that were not negotiated. While — when dealing with ratification decisions — we observe all the agreements that *could* but *are not* ratified. In essence, a study of ratification answers to the following question: Given that a treaty has been agreed, what leads countries to cooperate under the terms of the treaty?

2.1.3 Why does it matter?

We have just argued that international environmental agreements constitute a fundamental tool to address environmental problems in the 21st century. According to Spilker & Koubi (2016, p.224); "In the absence of supra-national institutions, voluntary cooperation between countries in multilateral environmental agreements is probably the only way to solve some of the most pressing environmental problems". Despite their relevance, the economic literature on treaty participation is mainly based on the game-theoretical approach and scarcely any observational data has been used to confront theoretical predictions with the patterns in ratification (Finus et al., 2017). We address this need for empirical evidence in an unprecedented attempt to test some of the main assertions of the literature on a large sample of countries and treaties. This type of analysis can lead to a deeper understanding of environmental agreements. In fact, a first look at the data already reveals that there is more variability in ratification than what would be expected by most of theoretical literature. In our treaty sample (Figure 2.3), there are more than 220 agreements that have more than 20% ratification rate and around 80 agreements that have more than 80% ratification rate. Figure 2.3 and 2.4 show that not only there is a wide variability in the ratification rate of treaties, but there is also a large disparity in the number of countries' ratifications.

What factors explain the difference in ratification between treaties, and why do certain nations seem to be more propense to participating in environmental agreements than others? The figures in this chapter seem to point to some of the factors explaining ratification rates. For example, the years of exposure affect the total number of treaties that a country can ratify (figure 2.4). A country that ceases to exist in 1990 or becomes independent in 1990 is exposed to less agreements than a country that has continuously existed and conducted international relations. But, figure 2.4 also suggests that other factors are at play. For example, the bottom five countries tend to be smaller nations and usually have very specific political and institutional reason for not ratifying. South Sudan — beside being the youngest nation in the world — is currently in the grips of civil war. Kosovo is politically unstable and several countries do not recognise it internationally. The Holy See is a very peculiar sovereign nation; being a religious state, it approaches international agreements differently and often prefers to remain impartial as shown by the fact that they renounced to their voting right at the UN, opting for the observer status instead. We also notice that the top ratifiers are all rich European nations. The fact that European

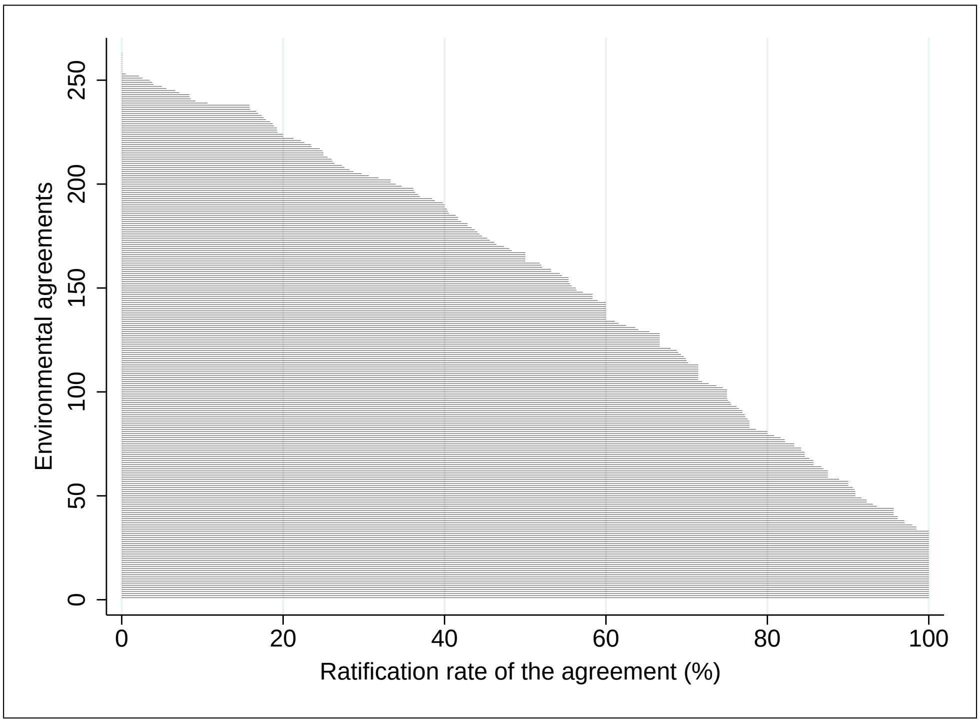

Figure 2.3: *Ratification rate of the environmental treaties in the data set*

Notes: Every horizontal bar represents a treaty. The treaty ratification rate is defined as the number of countries that ratified the agreement over the total number of potential ratifiers. For more information on the data see section 5.2 and 5.3.

countries can access a larger number of agreements (e.g. EU agreements) only partially explains their higher propensity to ratify. As a matter of fact, European countries do not just ratify a higher number of treaties, they also display some of the highest ratification rates (table 2.1). What pushes some countries to engage more in environmental cooperation? Is there some institutional, economic or cultural motivation that systematically affect the likelihood of ratifying?

From table table 2.1 we observe that countries with lower ratification rates are not necessarily the poorest, in general, political factors seem to be decisive. San Marino and Andorra are two small countries located in Europe. Although they are fully sovereign nations, with high levels of income, they also heavily depend on their neighbours both economically and diplomatically. These examples seem to suggest that a number of institutional and political factors are implicated in participation choices. This argument connects with figure 1.1, the map in the

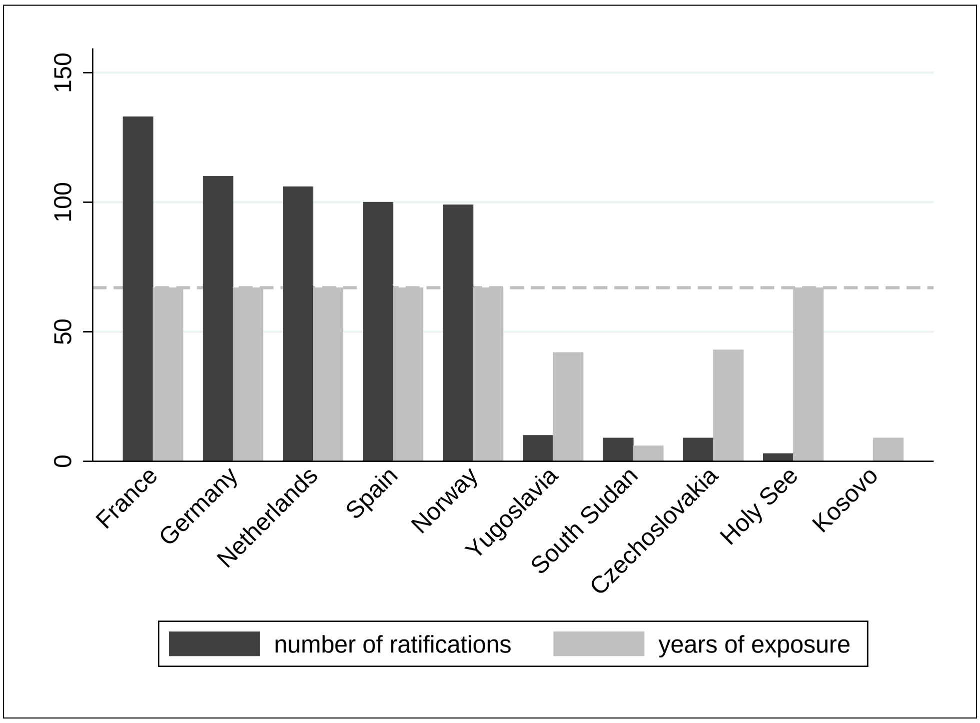

Figure 2.4: *Top five and bottom five ratifiers by number of ratifications*

Notes: Data on ratification is collected for the period 1950-2017. "Years of exposure" denotes the number of years the country exists in the data set. The data set covers the period 1950-2017, therefore the maximum value for "Years of exposure" is 67. For more information on the data see section 5.2 and 5.3.

introduction chapter depicting how the number of ratifications differ across the world. Not only are ratification rates widely different among nations, but they also seem to be clustered geographically rather than distributed randomly. All of these elements give the impression that there are country-specific factors explaining ratification rates, or even that decisions have a spatial context.

As we have seen, international environmental agreements present a series of interesting patterns that require deeper examination. So far, we know relatively little about the fundamental determinants of ratification. This is an interesting area of research that has direct relevance and concrete applications for policy makers. A better understanding of the ratification process can help frame more effective agreements and improve international cooperation on environmental issues. Given the importance of treaties in solving environmental problems and the ever more pressing need for international cooperation, it is fundamental that

Table 2.1: *Top five and bottom five ratifiers by ratification rate*

Country	Ratification rate (%)	Potential ratifications
Norway	83.89	118
France	82.10	162
Netherlands	81.54	130
Germany	81.48	135
Sweden	79.84	124
⋮	⋮	⋮
San Marino	11.76	102
Andorra	11.76	102
South Sudan	10.59	85
Holy See	3.75	80
Kosovo	0.00	80

Notes: Only countries existing in 2017 are included in this table. For more information on the identification of potential ratifiers see section 5.2.

agreements are used in the most effective way.

In summary, our study provides much needed empirical evidence for the existing theoretical literature (Finus et al., 2017). We also test some of the main conclusions of the recent game-theoretical literature using the largest data set ever applied to the question of environment treaty participation. Hence, we address an important gap in the literature. The scope of this research is to improve the understanding of the factors underpinning ratification. Why do nations take part to these agreements? What motivates them? What are the factors affecting these decisions? A systematic organisation of the existing theoretical and empirical literature has never been undertaken. Our work can positively contribute to the field by furthering the knowledge on the determinants of participation in environmental agreements. In the next section, we illustrate in more detail the main contributions of this thesis to the economic literature, and discuss how our findings can be used by policy makers and negotiators.

2.2 Contributions

This study brings a series of contributions to the literature on the participation in environmental agreements and directly tackles an existing gap in the extant body of research.

2.2.1 A new data set on ratifications

We confront the question of ratification with a new data set, comprising of 263 environmental agreements and 198 countries between 1950 and 2017. Our data tracks the ratification decisions over time for almost 20000 treaty-country dyads. It is one of the largest data set applied in this area; the only comparable in size is the BKKS (2010)[1] data set assembled by Bernauer et al. (2010) which covers 255 agreements and 180 countries (see table 2.2). The BKKS data set found application in most of the papers on environmental treaty ratification such as Bernauer et al. (2013b), Böhmelt et al. (2015), Spilker & Koubi (2016) and Mohrenberg et al. (2016). Nonetheless, it has important limitations that we seek to overcome.

Table 2.2: *Ratification data sets*

Data set	Treaties	Countries	Years	Regional treaties
Our data set	263	198	1950–2017	Yes
BKKS (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 a number of non-strictly environmental agreements, such as agreements referring to nuclear energy. Their sample also contains agreements more loosely related to the environment, some examples are 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

[1]For convenience, in this paragraph we call "BKKS" the data set assembled by Bernauer et al. (2010). Their data has been used in several other works: Bernauer et al. (2013b), Bernauer et al. (2013a), Böhmelt et al. (2015), Mohrenberg et al. (2016), Spilker & Koubi (2016) and Hugh-Jones et al. (2018).

Weapons (1972)[2]. Non-environmental agreements expand the size of the data set, but is likely to distort results in studies claiming to focus solely on environmental treaties. For this reason, 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 flaw lies in the inclusion of regional agreements without duly accounting for the different subset of countries they are open to. BKKS data set, as well as all the previous works in the area, implicitly assumed 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. In BKKS not all of the treaties are universal, some of them — by their very nature — 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 — for obvious reasons — would never be ratified by distant nations such as Nicaragua or South Korea. In their paper, Bernauer et al. (2010) admit that some of the agreements could be *de facto* open just to a restricted number of countries. In the appendix of the same paper, Bernauer et al. (2010) decide to run their model on a reduced sub-sample of treaties keeping only the agreements that have no obvious regional nature: the total number of treaties is halved to just 113 environmental agreements. If not addressed properly, this introduces a bias in the estimates, leading to underestimated ratification probabilities. The scale of the impact is hard to assess in previous works but it is potentially substantial.

We addressed this issue by identifying for every year, out of the 198 countries, all the potential ratifiers for each of the 263 treaties in our data set. The identification procedure is based on the scope and text of the agreements, a detailed explanation is provided in section 5.2.2. This feature is fundamental because it allows us to include regional treaties into our data set. This, in turn, leads to the third limitation of previous works: since most of treaties are regional, studying only global ones reveals only a small part of the picture. Our data set allows us to make generalisable predictions because of its size and the more representative sample of treaties on which it is based. Apart from Leinaweaver (2012), this is the only study that covers regional treat-

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

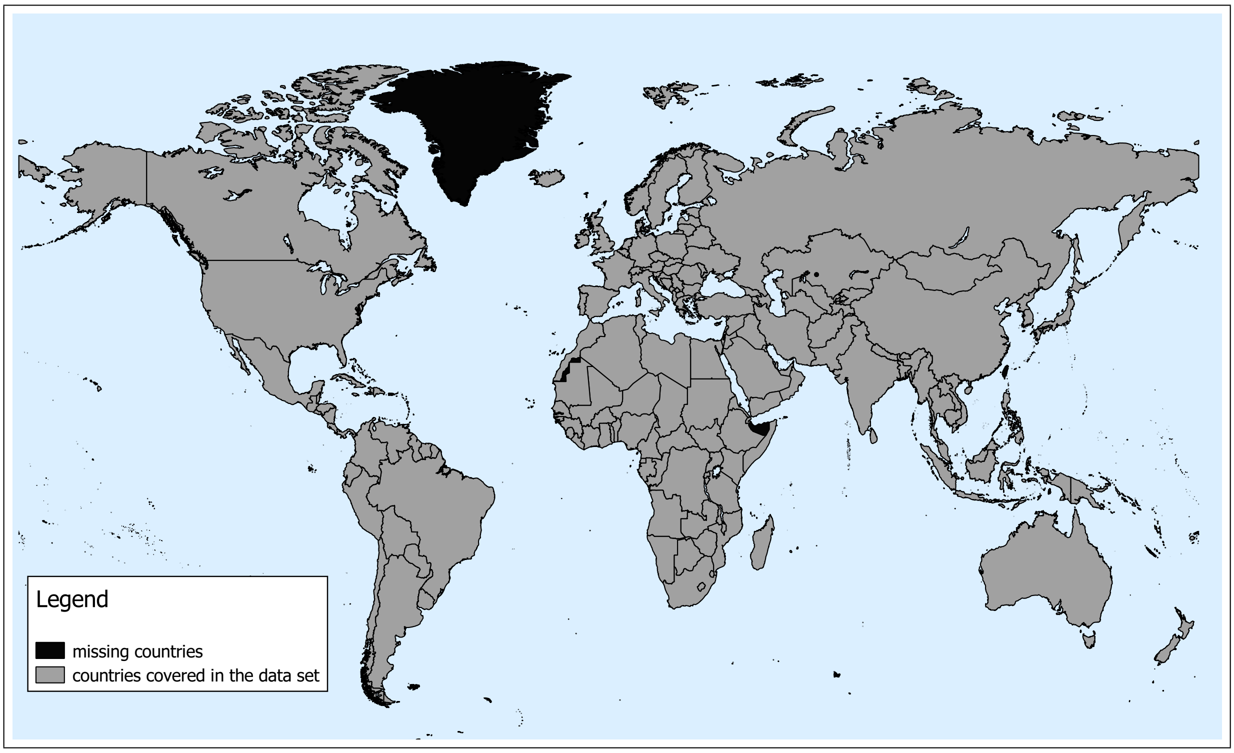

Figure 2.5: *Countries in the data set*

ies, despite the fact that most of environmental treaties are regional. Management of freshwater resources, protection of habitats and ecosystems, pollution of seas and lakes, etc.. Most environmental issues involve a limited number of countries, i.e. they are geographically narrow. Environmental agreements reflect this aspect, the largest part of the international environmental cooperation takes place on a regional scale.

In summary, not only does this thesis greatly expand the sample size, but it also corrects the potential bias subsisting related to the definition of the countries in the risk set. In fact, in order to produce reliable estimates it is necessary to know both the countries that ratified and those that could but failed to do so. The centrality of this assumption has been gravely overlooked, leading to the misidentification of several agreements and a general underestimation of the ratification probability. Defining the potential ratifiers to a treaty allows to correctly incorporate regional treaties in the analysis and produce reliable results for a more representative sample of treaties. Our new data set, allows us to produce an analysis based on a large number of agreements, including regional ones, which reflect more accurately the dynamics of environmental diplomacy.

2.2.2 A refined methodological approach

This study employs a survival model to study the probability of ratifying environmental agreements. The advantage of survival models is that they can measure ratification over an additional dimension, that of time. As a matter of fact, the decision to ratify an agreement is characterised by two dimensions: *i*) whether or not a treaty is ratified and *ii*) the timing of ratification. Survival models are able to take advantage of the heterogeneity in the time dimension, while a simple cross-sectional or panel approach can only pickup differences in the first dimension. Timing is crucial in the case of treaties that attain very high rates of ratifications, because in those cases most of the heterogeneity lies in the timing of ratification rather than its occurrence. Survival analysis is also capable of dealing with right-censoring and thus is better suited to the analysis of recent agreements that have ongoing ratifications. By using only information up to the moment of censoring, survival analysis does not conceptually preclude future ratification, therefore eliminating the problem of setting arbitrary cut-off dates that would otherwise affect the final estimates.

This thesis differentiates itself from previous studies of single agreements (e.g. Neumayer 2002b, Fredriksson et al. 2007 or von Stein 2008) in that the ratification of a large number of environmental agreements and countries are pooled together in order to build a general model of ratification. Unlike studies of single agreements, this approach allows the analyst to produce generalisable results instead of descriptive models for single treaties. This modelling strategy benefits from the large sample of regional and global treaties that we purposely collected, but also introduces a number of challenges. Arguably the biggest challenge is the treatment of unobserved heterogeneity, an aspect that has often been neglected in previous works (e.g. Bernauer et al. 2010, Mohrenberg et al. 2016 or Spilker & Koubi 2016). We propose to use multilevel modelling with cross-classified random effects to account for unobserved factors, both at the country and at the treaty level. This modelling approach accounts for unobserved idiosyncratic factors and ultimately enables us to draw reliable conclusions on the effect of different determinants on ratification.

Furthermore, the model is estimated with Monte Carlo Markow Chains (MCMC), a Bayesian estimator. This is the first time a Bayesian estimation technique is applied in this field. This method is chosen because it can produce precise estimates despite the complexity of the model. Standard maximum likelihood algorithms do not work with cross-classified multilevel survival models because of the structure of the random effects. Alternative methods of estimation such as Laplacian approximation or quasi-likelihood approaches (e.g. MQL, PQL) with constraints on the parameters do exist, but in most of the cases convergence is hard to reach because of the very large number of observations, the intrinsic low variability in survival data and the numerical integrations entailed by the structure of the random effects. Another advantage of MCMC is that it estimates the entire distribution instead of just point estimates. And, if desired, could incorporate *a priori* knowledge on the value of the parameters through the use of informative priors. With regard to the priors, we exclusively employ diffuse definitions and run a high number of iterations to exclude any influence on the posterior distribution. Being a simulation technique, the principal shortcoming of MCMC estimation is the very long estimation time.

As mentioned in previous section, this study also corrects for a misidentification bias existing in previous empirical studies. We ensured the regression is based solely on the potential ratifiers to the agreements by identifying for every treaty the nations that are eligible for ratification. This fundamental distinction not only corrects the bias in the survival estimates but also allows us to explore the differences in ratification between global and regional agreements. Compared to previous studies, the incorporation of a wide spectrum of regional and global environmental agreements makes our results more representative of the population of treaties.

Lastly, in the second part of the study, the results on international ratification are studied more in depth during their implementation phase. This is the first time a ratification study is coupled with the analysis of domestic environmental policies in order to draw conclusions on the implementation mechanics of environmental agreements and disentangle the effect of domestic pressure groups. At the national level, different environmental policies and indicators are studied with a methodological approach that accounts for idiosyncratic factors of the country. This innovative framework of analysis allows more robust results both on the participation in international agreements and the success of environmental domestic policies.

2.2.3 The gap in the literature

From the perspective of economics, an environmental agreement is an international public good that deals with transboundary environmental externalities (Beron et al., 2003). The prevailing theoretical framework is the following. Nations are seen as unitary agents that maximise the domestic social welfare. Environmental issues affecting a group of countries could be solved by negotiation and participation in international environmental agreements. However, countries also have an incentive to free-ride on environmental agreements to obtain environmental benefits without the costs associated with the treaty (Pearson, 2011). This dynamic has been treated by several economic models, mostly using game-theoretical approaches. These models predict optimal treaty design and participation levels. The conclusions are generally pessimistic on the capacity to solve the environmental problem beyond the non-cooperation level (Wangler et al., 2013). This prediction partly originates from the core assumptions of the models, in particular how free-riding incentives are defined and whether or not compensating mechanisms are included. In the traditional setting, the model leads to a trade-off between participation and the strictness of the agreement, which ultimately implies that abatement above the non-cooperative solution is very unlikely.

This framework has two major weak points. The first is that it assumes that ratification decisions are taken by a unitary and welfare maximising policy maker; in reality, domestic actors and interests play a major role in the decisions of the country (Marchiori et al., 2017). In this study, we explain how public choice theories integrate with the classic framework of economic analysis and empirically test some of the main predictions. The second point is that it generalises the incentive structure of treaties and over-simplifies the dynamics of ratification. The empirical literature emphasises the importance of other factors beyond those traditionally incorporated into economic models. For example, the presence of "peer pressure" effects between countries, as well as the impact of institutional and political factors are widely accepted in the empirical literature. However, these are rarely acknowledged in economic models of treaty participation. Hence, this study bridges the two bodies of literature and offers a broader framework to evaluate more realistically international environmental agreements.

This thesis addresses an existing gap in the literature and contributes in different ways to the research in the field. To start with, we test a number of theoretical predictions regarding participation in environmental agreements and the role of country and treaty characteristics.

In particular, we focus on the impact that domestic pressure groups and the quality of institutions have on the final decision and timing of ratifications. It is the first time these effect are studied on a large sample of treaties. The only comparable work by Fredriksson et al. (2007) focuses on a single treaty — the Kyoto Protocol (1997) — thus, it is not able to produce generalisable results.

As a matter of fact, some empirical studies on ratification have already been undertaken in the area of international politics and political science (e.g. Roberts et al. 2004, Schneider & Urpelainen 2013). They often focus on few specific agreements and their methodological approach does not allow to produce generalisable results on the mechanisms of ratification. There is some initial applied research in economics (e.g. Beron et al. 2003), however many important questions still remain unanswered. The analysis in this thesis noticeably expands the scope of previous studies and improves upon the methodological approach that has been used so far. Our empirical analysis introduces important new elements. For example, we seek to correct the treatment of potential ratifiers and of unobserved heterogeneity, two particularly delicate points. It is also the first time a wide study of regional environmental agreements is conducted. Furthermore, we also shed light on how the lobbying process operates both at the international and domestic level. We link our findings to the results in other studies and investigate how the relationship works during the implementation stage of treaties.

Furthermore, we also evaluate the incongruities between theoretical predictions and evidence of empirical works. To this end, we organise and review all the existing empirical literature on the subject. A systematic and comprehensive review of ratification studies was lacking. We believe this can help improve the understanding of the dynamics underpinning participation in environmental agreements and ease the communication between the game-theoretical and empirical fields of enquiry.

In summary, this work combines the existing evidences and theories with a new data set, a broader framework of analysis and a refined methodological approach. This research fits in the area of political economy, public choice and institutional economics. It is an attempt to bridge with the existing literature in international politics and address a gap in the economic literature. This research addresses aspects mostly — and surprisingly — overlooked, that considerably enrich the debate surrounding environmental sustainability and the political tools to achieve it.

2.2.4 Applications of the results

The model of ratification we build is intentionally *general*. It is used not only to derive conclusions on the role of institutions and pressure groups, but also to understand the forces that push and hinder the ratification of environmental treaties. However, the model can also be employed to generate predictions for specific countries or specific treaties. In the second part of our analysis we use our model to simulate ratification probabilities in different scenarios. We predict the probabilities for several countries of joining a hypothetical regional protocol and a global framework agreement. We also apply it to simulate out-of-sample ratification probabilities for a real agreement, the Minamata Convention on Mercury. These examples illustrate some concrete applications of the study.

The topic treated in this thesis has practical implications for treaty-makers and negotiators. Our findings can inform a more effective way of framing treaties in order to help building successful participation. Furthermore, the model developed here can be used to predict the probability of ratification and, if necessary, its structure could be expanded to accommodate more complex interactions. This thesis also sheds lights on the mechanisms that link domestic interest groups with environmental policies and the international actions of governments. The work is relevant to any entity that bears economic or private interest on environmental agreements. For governments, the results could be used to identify different areas of intervention at a national level and select the best strategy for the success of international environmental cooperation.

Chapter 3

Review of the empirical literature

This study is not the first to tackle the question of ratification, there are some precedents. Interest first arose in the domain of political science and slowly permeated into economics. Economics grew increasingly interested in political phenomena, partly because of the growing importance and recognition of institutional economics. Despite all this, international environmental agreements and their ratification only received marginal attention if compared to other political processes, and the field remains a young, yet dynamic, area of research. The first examples of empirical studies on ratification date from the 1990s, but significant development came in more recent times. In the course of the last 10 years a great progress has been made in terms of methodology and generalisability of results. However, the question of ratification remains mostly unexplored and with large opportunities for improvement.

The purpose of this chapter is to describe the state of the art and to take stock of the main results of the existing body of literature, with an eye to the questions that remain on the table. This chapter exclusively deals with the empirical literature; the theoretical background is treated separately, in the next chapter. This literature review represents the first comprehensive survey of the empirical literature on the ratification of environmental agreements. In the following sections, we review the works along the lines of their results, their methodological approach, and the questions they seek to answer. The chapter covers a broad number of articles and papers, which — to the best of our knowledge — represent the totality of the works published on the topic of environmental agreement ratification.

3.1 What did we learn about ratification?

The first thing that becomes apparent is that ratification is a complex event. There are many potential reasons for a country to ratify a specific treaty: economic, political, cultural, strategic, and of course environmental. Under the banner of ratification we group the act of adhesion to treaties that are structured differently, created by diverse group of countries under different circumstances and deal with disparate environmental problems on a very dissimilar geographic scale. In essence, ratifications are quite diverse, they all go under the same name, but the individual acts of ratification are heterogeneous and often motivated by different forces. However, despite all this diversity, there are some common threads that are recurrently linked to ratification. The empirical research has sought to dissect and understand these common threads, with interests ranging from the role of electoral rules and political systems to the incentives provided by trade openness and economic partnership. In this section, we will survey the main results of this strand of literature.

3.1.1 Political system

The ratification of environmental treaties is the outcome of a political decision. Therefore, a common thesis is that the political characteristics of a country have a bearing on their ratification behaviour. The literature in political science has been particularly keen on emphasising the role played by political factors. Then in more recent years, under the impulse of constitutional economics, a number of studies explored the link between political features and ratification behaviour. The influential works of Persson & Tabellini (2003) and Persson et al. (2007) highlight the link between constitutional features such as electoral rules (majoritarian vs proportional) or political systems (parliamentary or presidential) and their impact on economic development and other economic variables. These same features are tested with reference to ratification.

The role of democracy

One of the initial areas of interest is the link between the system of government and environmental diplomacy. Bernauer et al. (2010) states that democratic nations are expected to be more inclined to ratify because their leaders are accountable to the public. Democratic regimes offer higher access to information, and complete civil liberties, including freedom of speech, press and association. This pushes for higher transparency and accountability of the politicians in office. Neumayer (2002a) reiterates the argument, in his opinion, citizens of democratic states have better access to information on environmental problems and can exert more effectively political pressure on the government thanks to well functioning civil liberties. Democratic states allow to channel the ideas and preferences of citizens more effectively and increase the likelihood of joining international treaties (Recchia, 2002).

Congleton (1992) is the first to build a theoretical model for the selection of environmental policies in authoritarian and democratic states. The decisions in democracies depend on the median voter while in authoritarian regimes they are assumed to depend on the vote of the dictator or the median voter of a ruling class. All other agents or pressure groups are ignored. The model postulates that the authoritarian states have a higher price for the abatement than democracies. As a consequence, it predicts that authoritarian states are less likely to implement environmental policy and to sign environmental agreements. The difference in abatement price offshoots from the assumption that the median voter has a lower income share of the country and a longer planning horizon than the authoritarian regime because the turnover of dictators or the ruling class is faster according to Congleton (1992). In essence, the model states that in authoritarian regimes the ruling class is able to capture a higher share (compared to the median voter) of the economic benefits of having less stringent environmental regulations. Hence, they will be less likely to sign environmental agreements.

The empirical evidence seems to corroborate the link between democraty and participation in environmental agreements. Congleton (1992) formally tests his hypothesis on two treaties on Ozone Depleting Substances (ODS), he finds that democracies are more likely to sign than autocratic nations. Neumayer (2002a) explores the link between democracy and environmental commitment, measured by different indicators, one of which is ratification. Democracies tend to engage in environmental agreements consistently more than non-democracies. With a similar scope, Fredriksson & Gaston (2000) focus on the speed of ratification of the UNFCCC. They find that civil liberties and CO_2 emissions are strong determinants of ratification delay. There is a general consensus that democracy — in particular when measured by the degree of civil liberties and political rights — is an important factor behind ratification. In all the studies that followed, with no exception, the researchers have always controlled for the democratic characteristic of states (e.g. von Stein 2008, Perrin & Bernauer 2010, Seelarbokus 2014, Mohrenberg et al. 2016). The most common measures for the democratic extent of the government form are the two indices by Freedom House (2017) and Marshall et al. (2016).

Electoral dynamics and veto players

According to Nordhaus (1975), attention to environment is seen positively by electors, hence political leaders should show more environmental commitment before election. The argument is developed further by Cazals & Sauquet (2015). The authors posit that environmental treaties are unpopular in developed nations because they are seen as being onerous, hence they should be ratified shortly after elections. In contrast, developing nations are more prone to ratification during pre-electoral periods because they often have access to less stringent obligation or are granted financial assistance. In order to analyse the connection between electoral cycles and the timing of ratification, Cazals & Sauquet (2015) use a Cox PH model with time measured daily, to distinguish the pre- and post-electoral period. The sample covers the ratification of 41 global environmental agreements by 99 nations from 1976 to 1999. Their findings show that developing countries ratify just before elections to boost electoral results, while developed countries just after elections because treaties are seen as costly commitments.

In addition to influencing the timing of ratification, Schulze (2014) advances the hypothesis that the political alignment of the government influences the outcome of ratification. Schulze (2014) puts forward a series of arguments to explain the effect that party alignment has on ratification decisions. In order to enhance electoral success, political parties promote policies that correspond to the preference of the their electors. From this, Schulze (2014) concludes that government which are predominantly to the "left" should be more propense to ratify environmental agreements because environmental problems are more closely associated to the "left". However, the strength of this relation is questionable. There is a substantial lack of evidence to support the claim that *environmentalism* has any clear link to the "left/right" divide, and Schulze (2014) does not provide any justification for this assumption. Overall his study finds no significant effect of "left/right" divide on treaty ratification.

The process leading to the act of ratification often goes through several institutional bodies within the state. A veto player is an entity that has the power to block the act of ratification. It can be an individual, such as the head of state, or a group of individuals, such as the upper house of parliament. Given the fundamental role in the approval of ratification, the political alignment of veto players could affect ratification. Fredriksson & Ujhelyi (2006) find that the higher the number of veto players, the less likely is a country to ratify the Kyoto Protocol. Contrasting results are obtained by Cortez & Gutmann (2017), on a mixed sample of treaties — which includes several non-environmental treaties — in their study the number of veto players is not associated to a significant effect on ratification. Schulze (2014) formulates a second set of implications on the role of veto players; he postulates that what matters is the least "environmentalist" of the veto players and the orientation of the minister of the environment. With a sample covering 21 OECD countries and 64 treaties, he finds that indeed the "left/right" alignment of veto players has a significant effect on the chances of ratifying environmental agreements.

The constitutional side of ratification

The signature of the agreements is done by the executive, normally all or most of the negotiating countries end-up signing if the bargaining phase is successful. Most of the environmental agreements also require ratification, that is to say approval by the legislative branch. In most of the cases this requires going through the parliament but some countries consent ratification by the head of government (e.g. Israel and Bangladesh). Different countries have different procedures for the ratification of treaties. A number of studies enquire on whether the constitutional provisions on ratification can affect the likelihood of joining a treaty. This strand of research is influenced by the work in constitutional economics, which find that the characteristics of a political systems, notably electoral rules and government type, can have an influence on the provision of public goods (Persson & Tabellini, 2003).

Böhmelt et al. (2015) conceives treaty ratification as a process of public good provision. Their paper focuses on the effect of Environmental NGOs (ENGOs) lobbying on the ratification of environmental treaties. The effect is studied in the context of different electoral rules and government systems. In total the sample covers 75 democracies and 250 treaties from 1973 to 2002. Persson & Tabellini (2003) argue that there is a connection between the electoral rule and the number of political parties. Majoritarian systems, tend to have less parties than proportional systems. As a result, proportional systems are more prone to coalition governments (Persson et al., 2007). Böhmelt et al.

(2015) concludes that presidential systems with majoritarian electoral rule provide more public goods because the government represents a larger share of the population since they are characterised by a lower number of parties. The final conclusion is that presidential systems with majority rules increase likelihood of ratification. Böhmelt et al. (2015) also find that the lobbying of ENGOs is more effective in parliamentary systems with proportional rule.

Spilker & Koubi (2016) are interested to see whether parliamentary voting rules affect the ratification decisions of the country. Or, more precisely, if constitutional requirements for a supermajority instead of simple majority affect ratification probability. The study is conducted on a large sample of 220 treaties and 162 countries originally assembled by Bernauer et al. (2010). The results support the idea that "harder" agreements deter participation and that nations with constitutions requiring a supermajority vote by the parliament are less likely to ratify because they make the internal approval process significantly harder. A very recent paper on the subject is authored by Cortez & Gutmann (2017). They study the effect of different constitutional features on the number of ratifications by 99 democracies. Their main findings are that majoritarian systems and nations with independent judiciary are less likely to ratify international agreements. However, the robustness of their results is debatable. Cortez & Gutmann (2017) do not deal exclusively with environmental agreements, the article covers also other types of treaties but the empirical strategy lumps all the ratifications together and ignores any heterogeneity among treaties.

3.1.2 Economic factors

According to the prevailing framework, the characteristics of the country shape their set of incentives. The main factors affecting ratification are the income level and the trade structure. In this section we explore the link with economic fundamentals as well as the free-ride incentives predicted by economic theory.

Economic development

Income is a prominent factor influencing the participation in environmental agreements. Environmental agreements come with an economic cost that less developed nations are less eager to accept. The argument invoked to explain this thesis is the well known Environmental Kuznet Curve (EKC). The EKC identifies a bell-shaped relationship between the degradation of the environment and the level of per capita income.

The growth in income is first associated with a degradation of the environment which ultimately peaks and improves at higher levels of development. Empirical findings show that the bell-shaped relationship is not valid for all forms of environmental degradation and may vary considerably between countries and pollutants (Pearson, 2011). The theory behind the EKC postulates that at higher levels of income correspond a stronger preference for environmental improvements. Given that environmental agreements are a necessary — yet not a sufficient — condition for the resolution of transboundary environmental issues, economic development is associated with an increase in the likelihood of ratification (Bernauer et al., 2010).

The relevance of income differences is recognised by negotiators of environmental treaties. In order to reduce the effect of income, developing nations often push for systems that mitigate the costs borne by less developed countries, advancing that developing countries face other urgent priorities as — among other things — eradication of poverty and sustainable economic development. This is often recognised as as the "principle of common but differentiated responsibilities". Mechanisms such as economic and technical transfers, flexible deadlines or less stringent objectives are examples of clauses that aim at mitigating the impact of income on the participation in treaties.

Roberts (1996) stresses that developing nations, lacking infrastructures and with poor institutions, are less likely to ratify environmental agreements. The author argues that the development of a country mainly depends on its colonial past. Extraction colonies tend to turn into peripheral countries even after their independence because the political institutions and economic structure of the country were based on the extraction of raw materials to the benefit of the metropolitan power. History creates a persistent disadvantage. This thesis is further explored in Roberts et al. (2004) where the authors posit that extractive colonialism leads to a narrow base of exports that make countries more dependent on natural resources and less likely to ratify environmental agreements. By using diversification of exports as a measure for extraction colonialism, they predict that a narrow base of export goods is negatively related to participation in environmental agreements. Both Roberts (1996) and Roberts et al. (2004) are cross-sectional studies and cannot account for treaty characteristics nor control for unobserved country factors.The article establishes an original connection between the resource curse and participation in environmental agreements, however we believe that the final results might be affected by the omissions of important variables, such as GDP per capita, which is likely to influence the ratification decision and potentially correlates to their measure for extraction colonialism. The authors should have at least tried different indicators for the variables in order to assess the stability of the estimates. Indeed, the importance of income has been stressed in multiple occasions. Several studies confirm that richer nations tend to participate to a larger number of agreements (e.g. Seelarbokus 2014, Davies & Naughton 2014, Egger et al. 2011).

Pollution havens, trade and the incentive to free ride

When a group of countries — such as the Annex I countries of the Kyoto Protocol — commit to a reduction in carbon emissions, the uncommitted countries have an incentive to increase their emissions. This phenomenon is known as carbon leakage (Pearson, 2011). Carbon leakage occurs when stringent environmental regulations create a comparative advantage to the benefit of nations with more forgiving and lenient standards, to the extent that it is preferable for some companies to relocate in *pollution havens* or to substitute local production of carbon-intensive goods with import (Copeland & Taylor, 2004). Another possible explanation is that if a nation voluntarily engages into emission abatement, it will reduce the marginal damage everywhere else and, as such, will weaken the incentives of other nations to carry out similar policies (Felder & Rutherford, 1993). Basically, this argument posits that carbon leakage is a consequence of free riding on carbon commitments. Last, but not least, if a sufficiently large country decides to reduce its emissions, the demand and the international price of fossil fuels will decrease. This creates an incentive to use more carbon-intensive sources of energy in other countries (Pearson, 2011). Carbon leakage is a special case of the pollution haven hypothesis, according to which, pollution activity tends to concentrate in developing countries with more permissive environmental rules. The pollution haven effect is the fact that, at the margin, weaker rules on pollution, offer comparative advantage capable of inducing investment in pollution havens and changes in trade flows or trade composition (Copeland & Taylor, 2004).

There is an extensive economic literature on the relationship between environmental regulation and trade. The focus has been on the following two questions: does trade lead to lower environmental standards? And, does international competition create an incentive for lower environmental standards? As stated above, the pollution haven hypothesis advances a strong theoretical case for the link between environmental regulation and trade competitiveness. Nevertheless, the empirical findings are mixed. Although the majority of studies find no significant link between environmental regulation and trade, no consensus has been reached on whether asymmetric environmental regulation influences in a positive or negative way competitiveness of firms or whether trade has a systematic negative impact on the environment.

Grossman & Krueger (1995) investigate the relationship of several economic and environmental indicators to test the theory of the Environmental Kuznet Curve. In this context, Grossman & Krueger (1995) find no evidence that trade openness has a positive or negative effect on the environment. Antweiler et al. (2001) find that trade tended to reduce SO_2 concentrations in a sample covering 108 cities in 43 countries (mostly developed nations). This reduction is chiefly explained by the benefits derived from economic development, which stimulate technological innovation and efficiency in production. Similar results are found in several empirical studies, such as McAusland & Millimet (2013) for US-Canada trade and Dietzenbacher & Mukhopadhyay (2007) for India. Even on the pollution haven hypothesis the results are essentially mixed (Levinson 1996, Keller & Levinson 2002, Ederington & Minier 2003, Dean et al. 2009, Mulatu et al. 2010). A series of empirical complexities make it hard to assess unambiguously the impact of environmental regulation of trade flows. According to Millimet & Roy (2016), the empirical literature on pollution haven is inconclusive because of unobserved heterogeneity. Millimet & List (2004) posit that pollution haven effect has a heterogeneous effect within a country. Hence, it is hard to capture statistically. With intranational data on US' states they find that environmental regulation has a significative effect on the competitiveness of some states while others are mostly unaffected.

While the literature on environmental regulation is abundant, only a small subset of this body of literature has focused on the relationship between trade and multilateral environmental agreements. Kim (2016) builds a gravity model with a test for structural break to assess whether the Kyoto protocol induced a change in trade flows. With data on trade between G20 countries, Kim (2016) finds that a structural break has probably occurred in 2003. However, their model only controls for income level, distance and exchange rate. Hence, it is not clear if the breakpoint is linked to the implementation of the Kyoto Protocol (1997). Aichele & Felbermayr (2013) estimates the impact of commitment to the Kyoto Protocol (1997) on bilateral trade flows. They use matching variables with difference-in-difference estimation and find that the protocol induces a reduction of around 10% in the exports of Annex I countries, with energy-intensive industrial sectors being the most affected. The result is found by comparing average exports in the period 1999–2003 with the corresponding level in the 2004–2007 period. Difference-in-difference allows to control for time-invariant unobserved heterogeneity but not for varying unobserved factors. We suspect that the results could be inflated by a set of time-varying unobserved factors. First of all, the end of the second period corresponds to the an initial slow-down in world trade. Secondly, the study period also coincides with a major shift of industrial production towards developing countries and notably the surge of China in the world supply chain (after WTO accession in 2001). As an illustration, total exports of India grew from 60 billions USD in 2001 to 250 billions in 2007, and China exports exploded from 250 billions USD to 1250 billions USD over the same period[1]. In a subsequent paper, the same authors find that the Kyoto Protocol has an effect on trade composition. Aichele & Felbermayr (2015) employ a gravity model to calculate the embodied carbon in trade flows. They find that the embodied carbon in import of annex I countries increased by 8% and emission intensity by 3%. The changes in trade volume and trade composition suggest that environmental treaties may be able to influence trade flows. Nevertheless, results for international environmental agreements are mixed too. For instance, De Santis (2012) studies the link between three environmental agreements and trade with a gravity model. She finds that more stringent environmental policies tend to reduce exports. However, participation in environmental has the opposite effect: it increases exports. De Santis (2012) observes that bilateral trade among EU-15 countries increases in a significant way after the adoption of the Montreal Protocol (1987), UNFCCC (1992) and Kyoto Protocol (1997).

It has been suggested that the pollution haven effect partly contributes to the non-linear relationship between income and environmental quality of the EKC (Cole, 2004). This relationship is relevant also in another way. The choice of adhering to an environmental treaty cannot be considered separately from its economic implications. If the pollution haven effect holds, it could be advanced that a country that does not ratify an environmental agreement for strategic reasons may accrue an economic advantage in trade and foreign demand for pollution-intensive goods. The strength of this motivation can vary as a reflection of the environmental Kuznets curve. While this incentive may be appealing to poorer nations that value income growth more than environmental quality, it is not as attractive for rich countries with stronger preference for environmental quality. According to Bernauer et al. (2010), countries more focused on trade are expected to be less likely to ratify environmental agreements because they are more affected by a loss in comparative advantage. On the opposite,

[1]Data from World Bank (2017a).

Neumayer (2002a) argues that more intense trade leads to higher international integration and higher chances of participating to treaties. A similar argument is advanced by Egger et al. (2011) who posit that participation in environmental agreements increases with more liberal trade and investment policies. Sauquet (2014) states that the free-ride incentive in the Kyoto Protocol (1997) is mitigated by other types of relationships between countries such as trade partnership and proximity. There is a limited evidence on this. Beron et al. (2003) finds weak free-riding incentives for the Montreal Protocol (1987). On the contrary, Murdoch et al. (2003) observes that the abatement cost plays an important part in explaining the adhesion to the Helsinki Protocol (1985). The sample of Neumayer (2002a) covers 6 treaties and 175 countries and his results show that the level of imports and exports is important for the agreements that have trade restrictions, namely the Rotterdam Convention (1998), Montreal Protocol (1987) and CITES (1973). For the other treaties in the sample the results are not as significant. Furthermore, exporters of fossil fuels are less likely to ratify the Kyoto Protocol (1997) and GMOs exporters less prone to join the Cartagena Proctocol (2000). On a similar line, Wagner (2016) finds that trade relationships imply an acceleration of ratification time of the Montreal Protocol by 11%. However, the effect is likely to be stronger for the Montreal Protocol than for other treaties because it contains an explicit trade ban on CFCs commerce with non-ratifiers. The sample in these studies covers only a limited number of environmental agreements, but it seems to corroborate the interest-based explanation of Bernauer et al. (2010) and Murdoch et al. (2003).

Overall, there is no consensus on the relationship between trade and environmental agreements. According to the World Trade Organisation, there are currently around 20 international environmental agreements whose provision may have an impact on trade[2]. This may suggest that only a subset of treaties bears direct implications for trade flows.

3.1.3 Treaty design

One of the main reasons for the success or failure of a treaty is of course the content of the treaty itself. Stricter agreements impose higher costs on the parties and, all else equal, should attract fewer ratifications. The research on this subject is not well developed, the main limitation is the availability of data. This type of studies requires data that clas-

[2]`https://www.wto.org/english/tratop_e/envir_e/envir_neg_mea_e.htm`

sifies environmental treaties on their characteristics. At the moment, the main sources of information on the ratification of environmental agreements are either the text of the treaties or legal databases such as Mitchell (2017) and CIESIN (2013). Neither of these sources has a detailed classification of the characteristics of the agreements. As a result, the studies tend to be either on few agreements or on a limited number of features. In the second case there is often a problem of objectivity and consistency in the classification of agreements: some parameters can be classified in a clear-cut manner but many notions are more nuanced. Fundamentally, the research effort has focused on the *depth vs participation* trade-off, the main results will be summarised in the rest of this section.

There is evidence of a trade-off between strictness and participation in climate change agreements (von Stein, 2008). An early contribution is made by von Stein (2008), who analyses how the design of treaties affect participation levels. The author defines the strictness of environmental agreements on the basis of a number of characteristics. The main ones are whether or not the treaty entails obligations for the parties, the institution of decision bodies, flexibility mechanisms and the precision of environmental targets. They conclude that flexibility mechanisms are effective means to facilitate ratification and can be used to mitigate the dissuasive effect of tighter obligations. The problem of this study is that it is based solely on the UNFCCC (1992) and the Kyoto Protocol (1997), two large treaties on climate change, thus it is hard to generalise the results to environmental agreements as a group. Leinaweaver (2012) expands the sample of the analysis to a total of 55 regional and global environmental agreements. According to Leinaweaver (2012), the cost of committing to a treaty is mainly captured by three aspects: the presence of binding obligations, the acceptance of reservations and the existence of monitoring provisions. These are very similar to the factors discussed by Bernauer et al. (2010), and both derive from the concept of legalisation described by Abbott et al. (2000). The suggestion of Leinaweaver (2012) is that precise targets and agreements with participation thresholds for the entry into force tend to attract more ratifications.

With 200 environmental agreements, Bernauer et al. (2013a) is the largest cross-sectional study on this topic. They argue that "depth" is a complex concept that is reflected in several design features of an environmental treaty. The existence of formal obligations for the parties, monitoring, enforcement mechanisms, dispute settlement mechanisms, assistance mechanisms, and organisational apparatus are all factors that define the "depth" of an agreement according to the authors.

Their findings indicate that tighter obligations do reduce participation to agreements, but, contrary to expectations, stricter monitoring and enforcement do not reduce the likelihood of ratification. Finally, Spilker & Koubi (2016) consider different treaty designs and control for internal voting requirements for the approval of ratification. Their data is derived from Bernauer et al. (2010) and unlike Bernauer et al. (2013a) they use a survival approach. A treaty is considered "hard" if any two of the following dummies from Bernauer et al. (2013b) equals 1: *i*) the treaty states a precise target or standard, *ii*) includes monitoring and enforcement provisions, *iii*) includes dispute settlement provisions. Spilker & Koubi (2016) results strengthen the idea that stricter agreements deter participation. They also find that treaties that grant financial or technical assistance to developing countries have a higher chance of being ratified. This result echoes Mohrenberg et al. (2016), who observe that the institution or participation of a fund in the treaty reduces commitment costs and increases the likelihood of ratification.

3.1.4 International interactions

Foreign interactions are probably the most studied element in the ratification literature. Ratification is seen as a strategic move which does not only depend on the characteristic of the country and treaty, but also on the behaviour of foreign nations. Research focused on understanding the influence of global integration between countries at the economic and diplomatic level. The models also allow to break down the interdependence between different countries in order to see how the behaviour of other nations influence the outcome of ratification. A series of conclusions are derived on the linkage of nations.

Global integration

Political science literature brings the attention on the concept of integration between nations. This theory, called world-society (Frank, 1999) or constructivist theory (Yamagata et al., 2013), advocates that the more a country is linked to the international community through trade and diplomatic activity, the more likely it is to join environmental agreements. Recchia (2002) and Frank (1999) find that linkage to the world-society has a positive effect on ratification. The linkage is often proxied by the number of memberships to international organisations, international NGOs and international intergovernmental associations. Bernauer et al. (2010) explain that memberships to international organisations indicate openness to international cooperation, moreover, international organisations should increase information and reduce costs for the formation of multilateral agreements. According to Frank (1999) this is the main determinant of ratification, with an effect stronger than economic development, democratic government, natural degradation or scientific capacity. A similar conclusion is reached by Egger et al. (2013) who find that the size of the economy and previous treaty participation are the best predictors for the number of ratifications. Bernauer et al. (2010) compare domestic and international factors for ratification. International factors such as involvement in international organisations and ratification by foreign countries have a stronger impact on national ratification than individual domestic factors. Their study is conducted on a sample of 225 environmental agreements and 180 countries, which makes it the largest of all the existing studies in the literature.

Yamagata et al. (2017) illustrate a more complex relationship. The authors posit that before the fall of the Soviet Union countries would ratify following United States and USSR's ratification. As the international paradigm changed, the central factor for ratification became the integration in international relations (or proximity to world-society) and only weaker countries would follow the ratification of other nations. After 1991, weaker countries emulate the United States, or some other powerful neighbouring nation, while stronger countries ratify more independently. To sum up the interaction between ratifications of different countries changed with the shift in the geopolitical system.

The world-society theory predicts that the more a country is open to trade and the bigger its volume of exports, the more likely it is to ratify environmental agreements. However, the results of Neumayer (2002a) stress the economic side of integration and show that trading nations join environmental agreements because of the economic cost associated to trade restrictions rather than the "world-society effect". In addition to that, fossil fuel exporters tend to free-ride agreements on the abatement of fossil emissions (von Stein 2008, (Neumayer, 2002a)). All in all, it is possible that the effect of the memberships to international organisations is explained by other factors. For example, it has been suggested that when a country linked to the international community does not ratify a treaty, it suffers a loss in reputation and expects other nations to refuse cooperation in other areas (Bernauer et al., 2010).

Foreign influence

The ratification of a foreign country should create a free-riding incentive because it allows other nations to enjoy the environmental benefits without bearing the costs of ratification. Nevertheless, empirical evidence shows that often the ratification of a country, especially of powerful nations, has a positive impact on the ratification of other nations. This domino effect is partly explained by the existence of economic and political ties between countries (Sauquet, 2014); many authors have argued that these ties create interdependence.

The authors build a theoretical model of pollution tax competition with transboundary pollution spillovers. The model yields the following two predictions: *i*) when spillovers are between neighbours, countries have an incentive to lower environmental taxes to partially offset the environmental damage by attracting FDI. *ii*) At the same time, when spillover increase, countries also a stronger incentive to cooperate because mutual restraints (through environmental agreements) could yield larger gains in welfare. In the second part of their paper, the authors test whether participation in environmental agreements is responsive to the number of environmental treaties ratified by neighbouring nations. They provide evidence that neighbouring countries tend to cooperate more on environmental issues. Moreover, countries respond differently to OECD and non-OECD countries: the number of ratifications of OECD is found to be a significant determinant of the domestic number of ratifications, while for non-OECD countries it is not — except in regional agreement.

A nation is more likely to ratify if other countries already ratified the treaty (Bernauer et al., 2010). Bernauer et al. (2010) and Perrin & Bernauer (2010) posit that this is particularly true in the case of "peer nations", that are in the same geographical area or income bracket. These findings show that ratification by a country increases the likelihood of ratification by other countries, this is an encouraging effect which shows that the free-riding logic does not always apply. Sauquet (2014) reports that the likelihood of ratification for the Kyoto Protocol (1997) is affected by the behaviour of trade partners and partners in green investment projects, while neighbouring countries do not have a significant influence. His results are in contrast with Beron et al. (2003) who find that proximity and the volume of imports did not influence the way the Montreal Protocol (1987) is ratified. Probably, the free-ride incentives were weak for this particular treaty because of the trade restriction that it imposes to countries that do not ratify; hence the interdependence factor did not play a significant role in the ratification of the protocol.

Schneider & Urpelainen (2013) adopt a different approach to study the influence of foreign nations on ratification. The interest of the paper is focused on the soft power of the United States and European

Union. They wish to assess how the US and EU exert their influence over the ratification of environmental treaties. The study exclusively looks at the Cartagena Proctocol (2000) on biosafety regulation, where the United States opposed the EU because the treaty promoted the *precautionary principle* on GMOs which would have damaged United States' exports. According to Schneider & Urpelainen (2013), the two powers competed to influence the ratification of the treaty by third nations. Hence, the paper looks at how the strength of the ties with the US and EU affect the decision of joining the protocol. The more a country depends economically or diplomatically on one of the two powers, the more it should align its international policy with the great power. The analysis unveils that countries that are military allies or share strong economic bonds with the US have lower probability of ratifying the Cartagena Protocol, an agreement which advocates the European stance on GMOs.

Yamagata et al. (2013) and Yamagata et al. (2017) use a spatial lag model to explore the correlation in the ratification of countries. A weight matrix is applied to the ratification of other countries in order to aggregate their overall effect. They devise different matrices of weights to depict the ties between nations, based on: *i*) the number of international organisations to which both countries participate, *ii*) the presence of diplomatic representatives accredited between the two countries, *iii*) whether or not the countries belong to the same category of income group, *iv*) whether the countries have at least 50% of their population of the same religion, *v*) or share the same language (among English, Russian, Spanish, German, French, Portuguese, Arabic and Dutch). Only two climate change agreements are studied in Yamagata et al. (2013), but Yamagata et al. (2017) expands the analysis to 8 treaties. Yamagata et al. (2013) find that the ratification of the UNFCCC (1992) is dominated by constructivist theory: global integration is found to be the leading factor for ratification. On the other hand, foreign ratification seems to explain better the behaviour with relation to the Kyoto Protocol (1997). In Yamagata et al. (2017) foreign ratifications by the United States and USSR are pivotal before 1991, after the fall of the Soviet Union only the ratification of weaker nations is influenced by powerful nations, economic partners and neighbouring countries.

A last contribution on this topic comes from Wagner (2016). In the first part of the paper, Wagner (2016) builds a game theoretical model of treaty participation. In the second part the framework is tested empirically with data on the ratification of the Montreal Protocol (1987), preferential trade agreements and bilateral investment treaties. We will focus on the results related to the Montreal Protocol. The model essentially describes the delay in ratification, which depends on whether there is complementarity or substitutability in ratifications. In the long-run, the assumptions of the model imply that treaty ratification is inevitable. This theoretical framework can be transposed econometrically with an accelerated failure time survival model. Given that ratification is a certain outcome, this type of modelling is better suited to fit treaties that achieved universal ratification rather than predicting ratification outcomes.

The result of Wagner (2016) indicates that the ratifications of the Montreal Protocol exhibit strong complementarity. Wagner (2016) further estimates that, on average, the complementarity effect accelerated ratification time by 12% (208 days). The author argues that complementarity is mainly explained by 3 factors: *i*) Economic dependency, *ii*) Issue linkage and reputation costs, and *iii*) Fairness. The first point is particularly important for the Montreal Protocol because it entails trade restrictions on CFCs with non-ratifiers. The importance of bilateral trade relationships is embedded in the model through a weighting matrix that multiplies foreign ratification (in a similar fashion to Yamagata et al. (2013) or Murdoch et al. (2003)). In a second specification, Wagner (2016) accounts for reputational costs and issue linkage by recalibrating the above-mentioned matrix of weights with information regarding the participation of country dyads in 11 other major international treaties. Finally, concerns with fairness and equity are tested in a last specification that considers a treaty to be more equitable when a greater number of large polluters have decided to join the agreement. Again, this criteria of fairness is embedded by modifying the weights of the foreign ratification matrix. The results show that all these factors contribute to accelerating ratification compared to a model with no foreign interaction. Among the three factors, economic dependency seems to have the strongest acceleration effect on ratification timings. Bilateral trade relationships imply an acceleration of Montreal Protocol's average ratification time by 11%, and 7% if only trade in Ozone Depleting Substances are considered.

Signalling

Some researchers emphasise that the act of ratification signals about the feasibility of the environmental project and is used as a signalling tool to foreign and domestic actors. Perrin & Bernauer (2010) study the ratification behaviour of European countries for 9 long-range transboundary air pollution agreements (LRTAP). The focus is on the interdependence in ratification decisions. Their arguments are based on the literature on policy diffusion that stipulates that the adoption of a policy by a country conveys signals about reputation costs, competitiveness and implementation costs. These signals influence foreign countries in adopting the same policy. For example, in the optic of public choice economics, the government has an incomplete information on how the parliament or the electors react to certain policies. The adoption by another nation prompts national implementation because the consequences and costs are better known by the government. The results of Perrin & Bernauer (2010) suggest that the ratification choices of foreign countries or groups of countries influence domestic ratification process.

Schulze & Tosun (2013) hold that some countries are willing to ratify agreements and align their environmental standards with the EU because they anticipate potential returns in the form of aid, assistance, access to the EU market and even EU membership. Hence, some countries use the ratification of environmental agreement mainly as a signalling tool. The sample includes 25 non-EU members and 21 environmental agreements negotiated under the UN Economic Commission for Europe (UNECE). The results support the thesis of an European external influence in the area of environmental cooperation; the UNECE members located geographically more distant (e.g.Israel or Tajikistan) exhibit a lower propensity to ratify the agreements. On the contrary, the countries that aspire to join the EU and are economically dependent on the EU are significantly more likely to ratify environmental agreements. A similar analysis is conducted by Milewicz & Elsig (2014) covering 76 multilateral agreements, not exclusively environmental, and using survival analysis. They claim that new democracies in Europe ratify treaties to please the EU, signal political autonomy and gain international recognition. The findings are echoed by Cortez & Gutmann (2017), again with a sample not just limited to environmental agreements, who find that recent democracies are more likely to ratify all types of treaties. The higher rate of ratification strongly substantiates the quest for international recognition by young democracies.

According to Hugh-Jones et al. (2018), the signature of treaties is also used as a signalling device. More specifically, the authors argue that signature is used by the executive power to signal the importance of the issue to domestic and foreign veto players. Depending on national legislation, the ratification of an agreement might require the majority or super-majority and passes through different veto players (one or two chambers, courts, commissions, presidents, ...etc). The main argument of the authors is that these veto players see a high rate of signature as a signal summarising the importance and feasibility of the agreement. Their main conclusion is that the signature of a treaty increases the chances of ratification by the country.The empirical strategy of Hugh-Jones et al. (2018) suffers from a number of weaknesses. Firstly, they do not identify the potential ratifiers of every treaty. Since signatories are all potential ratifiers of the treaty while the group of non-signatories also contains countries that are not potential ratifiers to the agreement, it is very likely that signature could pickup the effect of this misidentification of the countries at risk. This has the result of biasing the effect of signature upward. In addition, Hugh-Jones et al. (2018) do not consider the fact that signatories are the most likely to ratify also because they were able to negotiate the treaty and are likely to be the countries that are the most interested in the agreement.

3.1.5 Results on lobbying and the quality of institutions

According to Putnam (1988) and Barrett (1998), ratification is the outcome of a two-stage game. The first is played internationally during the negotiation phase by national representatives. The second, domestically by the political institutions and interest groups. In this framework, ratification decisions boil down to the contrast between domestic actors. The effect of environmental and industrial lobbying on ratification has been studied mainly in 4 separate articles. The first two are Fredriksson & Ujhelyi (2006) and Fredriksson et al. (2007). These articles are almost identical and are the closest to our main research question, their main limitation is that they model exclusively the ratification of the Kyoto Protocol (1997). The effect of Environmental NGOs (ENGOs) on ratification is first studied on a broad sample by Bernauer et al. (2013a). The second article is Böhmelt et al. (2015); it studies how the number of ENGOs influences ratification decision under different electoral rules and government forms. Unfortunately, the latter two articles completely omit industrial lobbying. They are solely interested in the activity of ENGOs. The importance of domestic pressure groups is acknowledged more broadly. As a matter of fact, lobbying by either environmental or industrial groups is is included as a control variable in: Roberts et al. (2004), von Stein (2008), Yamagata et al. (2017), and incidentally also by Frank (1999) and Mohrenberg et al. (2016). In this section, we review in detail the findings and implications of these works.

Main findings on pressure groups

The main focus of Fredriksson & Ujhelyi (2006) is on lobbying and veto players. Veto players are defined as the political entities or individuals whose approval is required for the ratification of the treaties. In the first part of their article, a two-stage game is built to derive the equilibrium implications that are tested empirically. The theoretical model is based on the ability of firms and environmental lobbies to affect veto players through campaign contributions. In order to ensure ratification, environmental lobbies have to convince all veto players to ratify. Conversely, firms can secure non-ratification by simply gaining the support of a single veto player. As a result, ratification probabilities are lower when there is a larger number of veto players.

Fredriksson & Ujhelyi (2006) use data on the ratification of the Kyoto Protocol by 170 countries to test their assertion. They build a logit model as a benchmark and then a Cox PH model stratified on annex I/non-annex I countries with time measured in days. The data on ratification is censored less than 5 years after the signature; at that time only 51.7% of the countries had ratified. The early censoring could cast some doubts on the validity of the logit approach, because many ratifications are left out. The study only covers the Kyoto Protocol (1997), thus the generalisability of the results could be questioned. In addition to that, the empirical approach does not take into account international interdependence in ratification and, apart from the stratification of the survival model, lacks a strategy to control for country unobserved heterogeneity.

Fredriksson & Ujhelyi (2006) find that environmental lobbying, as proxied by the number of ENGOs, is a significant determinant of ratification, but the effectiveness is weaker for a higher number of veto players. On the opposite, lobbying by firms is unaffected by the number of veto players: this confirms that there is an asymmetry in the lobbying effect. However, industrial lobbying is not significantly linked to a lower ratification probability. The authors experiment different measures for industrial lobbying, such as the number of vehicles per capita, the intensity of CO_2 in commercial energy use, a dummy for "fuel" exporting countries, the presence of a national chamber of commerce or the membership to the World Business Council for Sustainable Development. In contrast with their predictions, the results consistently show no effect from industrial lobbying.

Fredriksson et al. (2007) mirror Fredriksson & Ujhelyi (2006) in the methodology, sample and results. This time, the number of veto players is replaced by the "integrity" of the government, the other variables in the model remain essentially the same. The ratification decision of a corruptible policy maker takes into account 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. The results indeed show that the ratification probability increases with environmental lobbying, and the more the government is prone to corruption the stronger is this effect. Again, industrial pressure does not seem to affect the outcome of ratification despite trying two new measures for industrial lobbying: the share of labour employed in the industrial sector and the share of fossil fuels in the exports of goods.

Additional results on the number of ENGOs

In the two papers presented in this paragraph, the authors focus on the number of ENGOs but unfortunately do not control for industrial pressure.

Bernauer et al. (2013a) analyse how the effectiveness of ENGOs' action varies in different democratic contexts. They argue that in more democratic nations the ENGOs can exert a weaker effect. Their first argument is that in democratic states the public demand for environmental cooperation is better channelled through the political system. As a result, the role of ENGOs diminishes. Political leaders of democratic states are more accountable and are more likely to satisfy the environmental demand. This argument mainly leads to the conclusion that political representation is more effective in democracies, but it does not necessarily downgrade the impact that ENGOs have on ratification. The two activities are not substitutes, it could be argued that ENGOs are more effective because of the more complete set of freedoms available in democracies. Then, they posit that in more democratic states ENGOs face higher competition for political influence. Regrettably, they offer no evidence justifying the crowding-out effect in democracies.

Bernauer et al. (2013a) use a Cox PH model, focusing on the time elapsing between signature and ratification for a large sample of environmental agreements. The results indicate that ENGOs have a positive effect on ratification, and in more democratic states the effect of ENGOs is reduced as predicted by the authors. Böhmelt et al. (2015) investigate more deeply the relationship outlined by Bernauer et al. (2013a). Their work focuses on the effect of ENGOs' lobbying on the ratification of environmental treaties in the context of different electoral rules and government systems. The sample covers 75 democracies and 250 treaties from 1973 to 2002. The findings show that the presidential systems with majority rule tend to provide more environmental public goods. According to the authors, this reduces the potential contribution of ENGOs' lobbying. On the opposite, ENGOs have a larger margin for action in parliamentary systems with proportional rule. Again, the results are in line with their contention. Bernauer et al. (2013a) and Böhmelt et al. (2015) share the same data and use a similar empirical strategy. Their main limitation is that they do not control for unobserved heterogeneity. Given the relatively frail theoretical backing for the relationships explored, it is possible that the main variables of the analysis capture the effect of some omitted variable.

Other interesting results

Mohrenberg et al. (2016) focus on the effect played by the participation of ENGOs (later defined more broadly as trans-national actors) during the negotiation of environmental agreements. This work differs from the previous ones because the emphasis is not on the pressure action of ENGOs, but rather on the degree of access that ENGOs enjoy during the development phase of the agreements. Mohrenberg et al. (2016) state that civil society access increases the transparency of negotiations and induces an improvement in the ratification of the treaty. Overall, they find a significant effect on the ratification outcome.

Yamagata et al. (2017) estimate a ratification model on a pre- and a post-1991 sample to highlight the effects that the fall of the Soviet Union had on environmental diplomacy; they include controls for environmental and industrial lobbying. The number of ENGOs per capita is used to proxy for environmental lobbying. It is found to have a significant effect on the ratification of 8 treaties in the period 1981-1990, but is never significant after 1991. On the other hand, industrial lobbying, measured by industrial production as share of GDP, is not significant before 1991, but reaches significance in a small number of specifications for the period 1991-2008. Industrial lobbying does not seem to have a strong effect on ratification also in their earlier article (Yamagata et al., 2013), in which they study the ratification of the UNFCCC (1992) and Kyoto Protocol (1997). In fact, their control variable for industrial lobbying never reaches the 5% significance level, whereas environmental lobbying does. Similarly, a measure for industrial lobbying measure is included in Sauquet (2014), but again, the relationship is not found to be significant for the ratification of the Kyoto Protocol.

While the effect of industrial lobbying seems perplexingly tenuous, the evidence for the quality of institutions is widely acknowledged.

Fredriksson & Gaston (2000) notice that developing countries tend to have slower ratifications, and link the delay to the inferior quality of institutions. Roberts (1996) and Roberts et al. (2004) maintain that peripheric countries and countries that experienced extractive colonialism are characterised by worse institutions; these institutions induce lower chances of ratifying environmental treaties. Good institutions foster ratification while aspects linked to bad institutions deter participation (Sauquet, 2014). In particular, corruption is often associated to lower chances of ratification (Seelarbokus, 2014; Fredriksson et al., 2007). As a further point, several aspects of the quality of institutions have been shown to interact with lobbying (Fredriksson & Ujhelyi, 2006; Fredriksson et al., 2007).

3.1.6 Conclusion

To sum up, we have presented all the main factors that are associated with the ratification of environmental agreements. For each factor we described the findings in the empirical literature. The determinants of ratification can be broadly grouped in 3 categories: *i*) domestic factors, *ii*) treaty characteristics and *iii*) international interactions. Domestic factors, such as the political system, the income level, the interests of dominant pressure groups, the quality of the environment, or the export structure of a country strongly shape the set of incentives and costs associated to ratification. The traits of a country play a fundamental role in explaining national interests, but they only partially explain the decision to ratify. The characteristics of the treaty are arguably even more important; agreements that promote stricter environmental regulations are relatively more onerous for the parties and, as such, are joined more reluctantly. Since there is no entity capable of enforcing a treaty internationally, the ratification of a country is entirely on a voluntary basis. All else equal, if the treaty entails costly commitments, countries are less likely to join also because of stronger free-ride incentives. Nonetheless, many authors have argued that this effect is mitigated by the strong interdependence between nations. Not only will ratifiers try to influence other nations to join, but economic and diplomatic partners might use the ratification of environmental agreements to reinforce partnerships and showcase their willingness to cooperate. As a result, a country is expected to be more likely to participate when it has stronger ties and connections with other ratifying nations.

In the next section, we discuss how the methodological approach evolved over time and review the strengths and weaknesses associated to each approach. The understanding of the different methodologies applied in the literature is used to assess the robustness of the findings and to guide us in the selection of the most appropriate research approach for the present study.

3.2 Evolution in the methodological approach

The act of ratification refers to a specific agreement, originates by a distinct country and occurs at a fixed point in time. In essence, it is qualified by three dimensions: country, treaty, and year. According to their methodology, the empirical research emphasised different combinations of these dimensions, looking from different angles at the same phenomenon. The methodological approaches followed a process of refinement and evolution, gradually attempting to include all 3 dimensions. The methodological shift entailed a change in the type of models and data, but also in the generalisability of the results and questions asked. We distinguish between 3 approaches: *i*) cross-sectional and count data, *ii*) survival analysis for single agreements, and *iii*) survival analysis for a panel of treaties. In this section we describe each of these approaches, their applications, limitations, characteristics and results.

3.2.1 Cross-sectional studies and count data

The cross-sectional approach is extensively used. It is the method used in the early studies dealing with the participation in environmental agreements, such as: Congleton (1992), Roberts (1996) and Frank (1999). The approach consists in looking at the status of ratification of one or more treaties, at a specific moment in time. The evolution through time is ignored and the focus is on the differences in ratification among countries. Ratification can be described in two different ways, the first is to concentrate on a single treaty and look at what country ratified the treaty, the second is to take the number of treaties ratified by each nation. In the first case a link can be established between the treaty and the country that ratifies. In contrast, the second measurement lumps together all the ratifications, thus losing all information on the specific treaties that have been ratified.

In both cases the first problem encountered by the researcher is to choose the right cut-off date. Since data is right-censored by construction, ratifications that fall beyond the observation date are ignored. For more recent treaties this could lead to misleading results because the selection of the observation point can arbitrarily influence the results. Beron et al. (2003) allow only 3 years for the ratification of the Montreal Protocol (1987), while in Murdoch et al. (2003) the observations on the Helsinki Protocol (1985) are taken after 5 years: In both cases a large number of the ratifications were not yet deposited by the time of the analysis. Congleton (1992), Neumayer (2002a) and Neumayer (2002b) study recent environmental agreements but mitigate the problem by focusing on the act of signature — which is typically concentrated in the first year of the treaty — instead of the act of ratification. The problem is particularly serious for studies that use the number of ratifications as dependent variable because different treaties are exposed to ratification for different amounts of time. All the studies mentioned in this section fail to address this issue, the only exception is Bernauer et al. (2013b) who account for the exposition factor by using a negative binomial model.

Table 3.1: *Cross-sectional studies*

Paper	Sample	Dependent variable	Model
Congleton (1992)	118 countries, Vienna Convention (1985) and Montreal Protocol (1987) on ODS.	Signature by 1989, binary variable.	Logistic regression.
Roberts (1996)	145 countries, 9 environmental agreements.	Weighted number of ratifications between 1963-1987.	Linear regression.
Frank (1999)	Total number of treaties is unspecified, number of countries ranges from 41 to 114 depending on time period.	Total number of treaties ratified by a country in the time period.	4 separate latent variable regressions for 4 time periods.

Cross-sectional studies (continued)

Paper	Sample	Dependent variable	Model
Neumayer (2002a)	6 agreements, maximum of 175 countries.	*i*) Survival data for ratification of 3 agreements. *ii*) Binary variable for the signature of 3 other agreements by 2000.	*i*) 3 Cox PH models for 3 treaties with high ratification rate. *ii*) 3 separate probit models are used for the signature of 3 more recent agreements for which ratification process is at its beginning.
Neumayer (2002b)	4 agreements with non-universal ratification, maximum of 175 countries.	Binary variable for the signature by 2000. The dependent variable is based on the signature of the treaties except for the Montreal Protocol (1987) for which ratification is considered.	*i*) Probit for signature dummy of individual treaties. *ii*) ordered probit for the sum of signature of agreements (from 0 to 4).
Recchia (2002)	15 global environmental agreements, 19 democracies.	Dependent is a score calculated by assigning a country 3 points for each ratified agreements and 1 point for treaties that are just signed.	Linear regression.
Beron et al. (2003)	Montreal Protocol (1987), 89 countries.	Binary variable for the ratification by 1990.	Probit with a matrix of weights based on trade volume to account for the interdependence in ratification between countries.
Murdoch et al. (2003)	Helsinki Protocol (1985) on sulphur emissions, 25 European countries.	Binary variable for the ratification by 1990.	Probit model.
Roberts et al. (2004)	22 agreements, 192 countries.	Index based on the number of ratifications between 1947-1999.	Linear regression.
Fredriksson & Ujhelyi (2006)	Kyoto Protocol (1997), 170 countries.	*i*) Survival data *ii*) binary variable for the ratification of the treaty by 2002.	*i*) Cox PH model with annual observations stratified on annex I/ non-annex I countries. *ii*) logit model.

Cross-sectional studies (continued)

Paper	Sample	Dependent variable	Model
Almer & Winkler (2010)	Kyoto Protocol (1997), 165 countries.	*i*) Binary variable for the signature and *ii*) ordered variable for the ratification of the protocol.	A latent variable approach is used for the binary variable (signature yes/no) and an ordered response model for ratification (ratified in period 1, 2 or 3).
Egger et al. (2011)	number of ratifications of 105 countries among 353 agreements signed between 1960 and 2006	Number of agreements in which a country is participating.	Panel approach. Linear feedback model for count data, estimated with GMM. The model includes a lagged dependent variable.
Egger et al. (2013)	number of ratifications of 110 countries among more than 212 agreements signed between 1960 and 2006	Number of agreements in which a country is participating. A model is estimated for every cluster of environmental treaties (atmosphere, land, sea, biodiversity protection, hazardous waste).	Panel approach. Linear feedback model for count data, estimated with GMM. The model includes a lagged dependent variable. The control variables are the same as in Egger et al. (2011).
Bernauer et al. (2013b)	200 agreements.	Total number of ratifications received by each agreement by 2006.	Negative binomial regression.
Davies & Naughton (2014)	110 environmental agreements, 139 countries over 1980-1999.	Number of agreements ratified during the year.	Panel count data. Spatial model: a matrix of weights based on the distance between the two countries is applied to the number of ratifications of foreign countries. The model includes a country and year fixed effect. Instrumental variable is used to address endogeneity in one of the variables. Estimated with GMM-IV and 2SLS.

Cross-sectional studies (continued)

Paper	Sample	Dependent variable	Model
Seelarbokus (2014)	110 environmental agreements, 108 countries.	Probably the dependent is the number of treaties ratified or signed by each country, not clearly specified by author.	Linear regression.

As mentioned earlier, the simplest way to "measure" ratification is to assign to every country a dummy variable that takes the value of 1 if it ratified and 0 otherwise. The ratification choice can then be modelled with a binomial regression to analyse how differences among countries affect the odds of ratifying. This approach has been implemented in numerous instances. Congleton (1992), Almer & Winkler (2010) and Neumayer (2002b) use it to model the signature of environmental agreements. Murdoch et al. (2003) and Beron et al. (2003) study the ratification of two different protocols by respectively 25 and 89 countries. Additional work is conducted by Almer & Winkler (2010) and Fredriksson & Ujhelyi (2006), both investigating the ratification of the Kyoto Protocol by circa 170 countries. These papers study exclusively one agreement, raising the question of how the results can be generalised beyond the single case. They fulfil a descriptive purpose, but offer little insight into the general process of ratification. Frank (1999) and Neumayer (2002a and 2002b) attempt to expand their results by including more than one agreement in their analysis but they limit themselves to very few of them because they still build individual models for each treaty. In principle, the approach could be extended to several agreements by using ratification dummies for treaty-country dyads (or pairs); even so, this strategy has never been implemented.

There is a second way to "measure" ratification for various agreements at the same time, which is by counting how many are ratified by each country. Then, it becomes straightforward to fit a linear or count model to evaluate the impact of country characteristics on the number of ratifications. Using a *ratification count* as dependent allows to easily expand the base of treaties included in the analysis because less information is required. Recchia (2002) covers 15 environmental treaties, Roberts et al. (2004) 22 and Seelarbokus (2014) reaches 110 agreements. This is considerably more than any other cross-sectional study using dummies. Nonetheless, using the number of ratifications is misleading. Do more treaties lead to stronger environmental commitment? Environmental agreements are profoundly different among them: adding treaties up is like summing grapes and melons. The number of agreements that are ratified is not necessarily proportional with the environmental commitment of the country or its level of international cooperation. To a large extent, the number of ratified treaties is just a reflection of the number of treaties the country is able to access. To this end, it is critical to know the number of neighbours and environmental issues in which a country could be involved. As an illustration, Kiribati is an insular state in the pacific, despite its interest in preserving the environment, it undoubtedly ratifies fewer agreements than Indonesia, a big state with several neighbours and a rich natural asset. Neither Seelarbokus (2014) nor Roberts et al. (2004) controlled for these factors.

We suggest that ratification rate would be a better measure than the number of ratifications, of course, this would entail identifying the potential ratifiers of each treaty, a practice that we are the first to implement. There has also been some attempts to use a system of scores instead of ratification counts. They usually work by assigning points for signatures and ratifications (Recchia, 2002) or by weighting the number of ratifications by the total number of ratifiers (Roberts, 1996). It is not clear what these indices could teach about the ratification of environmental agreements. In general, score systems tend to obfuscate the results, making the relationship between variables less clear.

A less obvious consequence of using *ratification counts* is that the connection between the ratifying country and the ratified treaty can be maintained only if each agreement is studied individually. That is to say, if we sum all the ratifications of a country, we would not be able to tell which treaty it has ratified, except in the trivial cases in which it has ratified none or all of them. This feature is a serious limitation to using a counting variable because it does not consent to tackle how the design of the treaty influences ratification. The characteristics of a treaty can be accounted for only by studying a cross-section of treaties and counting the number of ratifications it has received, just as in Bernauer et al. (2013b). However, this would imply that it would no longer be possible to know what country ratified, and consequentially investigate the role of country characteristics. With this type of dependent variable a trade-off exists between studying country or treaty characteristics.

An additional problem of cross-sectional studies is that they do not take into account the dynamics of ratification. As a matter of fact, many domestic characteristics are likely to influence the timing rather than the happening of ratification. The sequence and timing also matter for understanding the factors that affect ratification. For example, Spilker & Koubi (2016) analyse how different voting requirements for the ratification of international treaties influence the likelihood of ratification. It is reasonable to expect that complex or strict requirements should make the adoption of a treaty not just harder, but also slower. Their results support this view, countries that require supermajority for the approval of treaties are slower and less likely to ratify environmental agreements. Moreover, if time is ignored, it is also impossible to discern the order in which different countries decide to join a treaty, which in some cases provide strong evidence of the diplomatic interactions at play (Almer & Winkler, 2010).

The obvious solution to the omission of time is to use stacked cross-sections to create a panel data; this approach has been attempted by Davies & Naughton (2014) and Egger et al. (2011 and 2013). Davies & Naughton (2014) study participation in 110 environmental agreements by 139 countries over 20 years (1980-1999). The dependent is a count of ratifications. The study has a very robust methodological approach; the only weakness of the paper relates to the use of count data. Davies & Naughton (2014) build a spatial model and experiment different estimators (notably 2SLS and GMM-IV). They use instrumental variable approach to address endogeneity in one of the variables (FDI) and the model includes a country and year fixed effect to account for unobserved heterogeneity. Unfortunately, the use of count data invalidates the effort of Davies & Naughton (2014). Their objective is to determine whether ratification is sensible to the participation by neighbouring countries and to assess the link between FDI inflows and environmental policies. The problem with choosing the count of ratifications as dependent is that does not really consent to understand interactions between countries. Does the fact that foreign nations ratified a higher number of agreements mean that they had an impact on the domestic ratification choices? How do we know they ratified the same agreement? Could it not reflect the fact that a larger number of agreements have been agreed and are open to ratification? The research question cannot be properly answered because ratification count data does not allow to compare ratification choices within the same agreements. As with the previous study, the dependent variable in Egger et al. (2011) and Egger et al. (2013) is the number of agreements in which a country participates at any given point in time. The definition of "participation" is not clear in the 2011's paper: it appears that a country is considered to be a participant if it, indifferently, signs or ratifies an agreement. However, in Egger et al. (2013) reference is made to the act of ratification. Their data covers the ratification status of around

350 treaties for 105 countries — of which only 17 LDCs, suggesting that there could be sampling bias. The same control variables and methodological approach are used in both papers. In both Egger et al. (2011) and Egger et al. (2013) a dynamic feedback model for count data with lagged dependent variable is used to model the number of ratifications. The main difference is that in Egger et al. (2013) a separate model is estimated for different clusters of environmental treaties (atmosphere, land, sea, biodiversity protection and hazardous waste).

Egger et al. (2011 and 2013) and Davies & Naughton (2014) are the only studies attempting a panel approach with count data. The main downside of a panel approach with count data is that it does not allow the analyst to escape the trade-off between country and treaty characteristics. If the dependent variable is the number of ratified treaties by the country at time t, then we are not able to know what treaty the country has ratified, and as a result, the characteristics of the treaties cannot be used to explain its ratification. In the same way, if we tracked the number of ratifications that the treaty received at time t, then we are not able to discern which country ratified and take into account the characteristics of the country in ratification choices.

In summary, cross-sectional studies ignore the precious information conveyed by the timing of ratification. If, on the one hand, this constitutes the core of its weaknesses, on the other hand, it makes the data assembly and analysis noticeably easier. The papers adopting this approach study only a small number of treaties, many focus exclusively on an individual treaty (e.g. Murdoch et al. 2003, Beron et al. 2003 and Fredriksson & Ujhelyi 2006). We have observed that it is more of a convention than a necessity, because the approach could be extended to a larger number of treaties. We have also described the two cases in which count data had been used in a panel setting. The main issues with this strategy are the aggregation of treaties and the fact that treaty and country characteristics cannot be studied at the same time. These two aspects make the approach unsuitable to most research questions. The opposite to counting ratifications consists in focusing on a single agreements. Concentrating on single agreements allows for very specific models, tailored to the individual characteristics of the treaty, but this comes at the cost of generalisability. These models fulfil mostly a descriptive role. It is hard to infer any general advice from them. In the present literature, cross-sectional studies have limited themselves to studying only one dimension, either countries or treaties. However, the consensus is that both these dimensions concur in determining ratification with equal importance, and that time also has a central role in the equation.

3.2.2 Survival analysis

The awareness that timing is as relevant as the occurrence of ratification prompted for a revision in the methodology. The revision came under the form of survival analysis. In this section, we only review the studies that concentrate on single treaties, but this methodology can be extended to a plurality of agreements as described in the next section. Survival analysis is used to study the probability of an event at a specific point in time, and derives its name from the epidemiological background of the technique. Instead of just considering whether or not a country has ratified, we also look at when ratification takes place. From the moment the treaty is agreed, the country is *at risk* of ratifying it. The characteristics of the treaty and of the country are implicated in determining the chances of "surviving" to ratification.

The observation period starts when the treaty is opened for ratification; this usually occurs right after agreeing the text. From that moment, the country is at risk of ratification. Ratification by different nations is then tracked throughout time until the cut-off (censoring) year. For completeness, we report the final observation year in the second column of table 3.2. Ratifications taking place after the censoring year are not taken into account. Nevertheless, survival analysis is designed to cope with right-censoring. Results are unbiased as long as the assumption of non-informative censoring is satisfied.

The first application of survival modelling to ratification is in Fredriksson & Gaston (2000). They argue that a quicker ratification is linked to stronger environmental commitment on behalf of the country. This relationship is fallacious because the timing of ratification equally depends on frictions encountered during the internal procedures of ratification. Fredriksson & Gaston (2000) fail to account for the institutional aspect of ratification timing. In subsequent research, it is realised that time to ratification is a better dependent variable than the simple occurrence of ratification, because many factors result in changes in timing rather than occurrence. This notion is particularly important for studies focusing on political and economic variables. In fact, at the margin, a slightly more complex bureaucratic system or a small increment in the pressure of environmental groups are more likely to affect the timing rather than completely reversing the outcome of ratification.

The advantage of survival approach is that it can measure ratification over an additional dimension: that of time. Neumayer (2002b) uses this approach to his advantage when he notices that the cross-sectional approach is unable to detect variability within almost-universally ratified treaties. He applies the technique to the Montreal Protocol (1987), CITES (1973) and the Biodiversity Convention (1992), which by the time of the analysis had already been ratified by a very large number of nations. In general, survival analysis is a superior approach for universally ratified treaties because it takes advantage of the heterogeneity in the time dimension, while a cross-sectional approach fails to capture any differences in the ratifications when almost all countries have ratified. Survival analysis is also capable of dealing with right-censoring and thus it is better suited to the analysis of recent agreements with ongoing ratification.

In table 3.2 we have grouped all the studies modelling single environmental treaties with survival analysis. In total we count 8 different papers although most of them concentrate on the same two agreements, namely the Kyoto Protocol (1997) and the UNFCCC (1992). Climate change agreements received meticulous coverage because of the high media exposure, but also because of the rich anecdotal political literature surrounding the negotiation and participation to climate treaties. The COP[3] meetings are scrutinised by political scientist (Roger & Belliethathan 2016, Dimitrov 2016) and negotiation dynamics (Brandt & Svendsen 2004, Babiker et al. 2002), rules (Nasiritousi & Linner, 2016) and balances (Afionis 2011, Kasa et al. 2007) are carefully studied to explain countries' order of ratification (e.g.Andresen & Agrawala 2002, Lund 2013, Chin-Yee 2016). Survival analysis suits this branch of literature because it permits to test the ratification sequence. Neumayer (2002b), Wagner (2016) and Schneider & Urpelainen (2013) are the only papers on different agreements. The latter is an interesting case study of the Cartagena Proctocol (2000), an agreement regulating the use of Living Modified Organisms (LMOs). The protocol puts forward the "precautionary principle" endorsed by the EU, which would have damaged the agricultural exports of United States by setting unfavourable international standards on LMOs. The United States strongly opposed the agreement and advocated the "sound science principle". Hence the Cartagena Protocol is seen by the author as a natural experiment to test the extent to which foreign influence and international bonds with the Unites States and EU affect the ratification behaviour of third states. Again, the choice of survival modelling is linked to the need of studying the order of ratification in time by different countries,

[3]Conference of the Parties (COP) is the annual meeting of the members to the UNFCCC (1992), Kyoto Protocol (1997) and the Paris Agreement (2015). National delegations gather to "keep under regular review the implementation of the Convention and any related legal instrument" (Art.7, UNFCCC 1992). COP meetings are attended by thousands of participants from NGOs, scientific organisations, universities, government bodies, industry representatives, media, and civil society in general.

something that is easily performed with survival analysis.

Time is treated as continuous despite the fact that models are based on yearly or monthly observations of ratification. Furthermore, the explanatory variables are always measured yearly, so a common assumption is to take their values as constant throughout the year, if the model is specified for monthly (von Stein 2008 and Schneider & Urpelainen 2013) or daily ratification (Fredriksson & Gaston 2000 and Fredriksson et al. 2007). The distinction between continuous and discrete observations often is a nuanced one. The ratification of an international agreement is *per se* a continuous process, however it is registered on more or less narrow time intervals (years, months, weeks or days). Technically, it is a grouped survival data because an underlying continuous process is observed discretely, hence the observations are grouped over an interval. Despite the discreteness of the data, the variable could be assumed as continuous depending on the granularity of the analysis. Shorter observation intervals, such as days or weeks, over a long enough time period could easily be considered a continuous representation of the ratification process. For annual observations the assumption is harder to justify (Neumayer, 2002a). Yamagata et al. (2013) and Sauquet (2014) are the only papers opting for a discrete approach.

The Cox proportional hazard model is the model of choice in the majority of the cases (Fredriksson & Gaston 2000, Neumayer 2002a, Fredriksson & Ujhelyi 2006, Fredriksson et al. 2007, von Stein 2008 and Schneider & Urpelainen 2013). Cox PH is a popular semi-parametric survival model that does not assume any particular distribution for the survival times. The shape of the baseline hazard remains unspecified, unlike in the Weibull and the Gompertz models used by Sauquet (2014). In proportional hazard models, the explanatory variables affect the hazard rate of ratification in a multiplicative fashion. For instance, being a fossil fuel exporter may halve the hazard of ratifying a given environmental agreement. Furthermore, the hazard ratio is assumed constant over time, implying that the relationship between the explanatory variable and the hazard ratio never changes. Proportional hazard models are different from accelerated failure time models which describe the speeding up process of an event. Wagner (2016) is the only ratification study that uses an accelerated failure time model. In AFT models, the dependent variable is the ratification time instead of the hazard of ratification (probability of ratification at time t given no previous ratification). With the exception of Wagner (2016), all the models presented in this section are proportional hazard models and assume a baseline hazard shared among all the units of the analysis. It is a simplifying assumption that could clash with the structural diversity in ratification behaviours of nations. The samples contain diverse groups of nations but, save for Fredriksson & Ujhelyi (2006) and Fredriksson et al. (2007) that stratify their models on annex I and non-annex I countries, there is no attempt to address the unobserved heterogeneity at the country level.

In summary, the survival approach unlocks the third dimension: time. Survival analysis is also more suitable to right-censoring and treaties with high ratification rate. The studies presented in this section focus exclusively on single agreements. As a consequence, the conclusions of these models still do not generalise well beyond their sample, but they offer precious insight into the dynamics of treaty participation. The Kyoto Protocol and UNFCCC have been extensively studied, while other environmental agreements have been generally neglected. In the next section we will show how the survival approach is extended to treat several agreements at the same time.

Table 3.2: *Survival analysis for single treaties*

Paper	Sample	Dependent variable	Model
Fredriksson & Gaston (2000)	UNFCCC (1992), 184 countries until 1997.	Ratification survival time, daily observations.	Cox PH, the explanatory variables are assumed constant over the year (also modelled as cross-sectional logistic regression in appendix).
Neumayer (2002a)	6 agreements, maximum of 175 countries until 2001.	*i*) Annual survival data for ratification of 3 agreements *ii*) Binary variable for the signature of 3 other agreements by 2000.	*i*) 3 Cox PH models for 3 treaties with high ratification rate. *ii*) 3 separate probit models are used for the signature of 3 more recent agreements for which ratification process is at its beginning.
Fredriksson & Ujhelyi (2006)	Kyoto Protocol (1997), 170 countries until 2002.	*i*) Daily survival data on ratification *ii*) Binary variable for the ratification of the treaty by 2002.	*i*) Cox PH model stratified on a dummy for annex I countries. *ii*) Logit model.

Survival analysis for single treaties (continued)

Paper	Sample	Dependent variable	Model
Fredriksson et al. (2007)	Kyoto Protocol (1997), 170 countries until 2002.	Ratification survival time, daily observations.	Cox PH model stratified on a dummy for annex I countries (robustness checks are performed also with a Weibull model and a logit cross-sectional regression).
von Stein (2008)	Kyoto Protocol (1997) and UNFCCC (1992), maximum of 140 countries until 2003.	Ratification survival time, monthly observations.	Separate models are built for each treaty, in both cases a Cox PH and a Weibull specification are used.
Schneider & Urpelainen (2013)	Cartagena Proctocol (2000), 182 countries until 2006.	Ratification survival time, monthly observations.	Cox model with monthly observations allowing for non-proportional hazard. (Cross-sectional logit model in robustness checks).
Yamagata et al. (2013)	Kyoto Protocol (1997) and UNFCCC (1992), maximum of 166 countries until 2008.	Ratification survival time, annual observations.	Logistic regression for discrete survival data, with weight matrix to account for the network relationships between countries (spatial regression).
Sauquet (2014)	Kyoto Protocol (1997), 164 countries until 2009.	Ratification survival time, annual observations.	Gompertz survival model for grouped observations with lagged spatial variable for foreign ratification.

Survival analysis for single treaties (continued)

Paper	Sample	Dependent variable	Model
Wagner (2016)	Montreal Protocol, Preferential Trade Agreements (PTA) and Bilateral Investment treaties (BIT). 140 countries for the Montreal Protocol, until 2015.	Ratification survival time, daily observations.	Accelerated failure time model estimated with the method of simulated momemnts (MSM). The model includes lagged spatial variable for foreign ratifications. The baseline ratification payoff increases exponentially over time. Hence, by assumption, ratification is certain in the long-run.

3.2.3 Pooled survival analysis

The survival approach can be extended to several treaties simply by pooling together the survival information of more than one treaty. Strictly speaking, the techniques used here are the same as in the previous section; the only difference is that, instead of dealing with countries, the unit of analysis is the country-treaty dyad. Bernauer et al. (2010) is the first study that pools together various treaties in a single survival model. In the following years the same approach has been applied multiple times. In fact, most of the recent studies choose to adopt this method over the ones described in previous sections. This approach yields coefficients that are general; they do not fit the specific treaty, instead they are intended to represent the process of ratification as a whole. This quality makes survival approach particularly suitable to our analysis. From a methodological point of view, pooled survival models are more complex because they need to account also for the heterogeneity at the treaty level.

The first advantage of pooling different treaties together is that the number of observations is remarkably larger. The total size of the sample can be extended in any of the 3 dimensions of the analysis, by including more treaties, covering more countries or by increasing the time frame. For each treaty-country dyad the beginning of the observation period corresponds to the signature year of the agreement and ends either with ratification by the country or on the last observed year. The second column of table 3.3 reports both the final observation year and the earliest signature year for each study. Most of the studies presented here use the ratification data collected by Bernauer et al. (2010)[4]. Their data set is notably larger than all previous ones; it covers 180 countries and over 250 treaties. While the works described in the previous two sections mostly focus on big environmental agreements, the data collected by Bernauer et al. (2010) allowed to diversify and expand the analysis to a profusion of smaller and less famous agreements, considerably enriching the debate on ratification. In comparison, other data sets are relatively narrow in terms of countries and treaties. For example, Schulze (2014) just focuses on OECD countries and Leinaweaver (2012) cover 198 countries, but only 55 agreements.

The downside of pooling together many treaties is that it introduces the risk of sampling bias. In order to obtain valid general ratification estimates, the sample needs not just to guarantee unbiasedness with respect to the exclusion of countries, but also to be representative of the whole population of environmental treaties. Regrettably, the risks associated to sampling bias have not been thoroughly analysed in the context of previous studies. In the bigger studies we find no evaluation of the potential distortions deriving from the exclusion of countries with missing observations in the explanatory variables[5]. And in the same way, the constitution of the treaty sample has rarely been assessed. Generally, regional environmental agreements have been either neglected or incorrectly handled in previous works.

Most of the ratification studies concentrate on *global* agreements (Bernauer et al. 2013a, Cazals & Sauquet 2015, Yamagata et al. 2017). These are the ones that are open to all nations and to which every nation is *de facto* a potential ratifier. The trouble is that, except for the studies focusing on specific treaties or group of countries (Perrin & Bernauer 2010, Schulze & Tosun 2013, Schulze 2014, Yamagata et al. 2017), many less-than-global agreements have inadvertently been mixed with global ones. We call *regional* all the treaties that are not strictly global, with no distinction for their scale. The real problem is not that regional agreements have been included in the analysis, but rather that they were not correctly handled. After all, most of envir-

[4]Their data set is used in the following works: Bernauer et al. (2010), Bernauer et al. (2013b), Bernauer et al. (2013a), Böhmelt et al. (2015), Mohrenberg et al. (2016), Spilker & Koubi (2016) and Hugh-Jones et al. (2018)

[5]Missing observations occur among the explanatory variables rather than in the dependent. By construction, survival data on ratification has no discontinuity and is never left-censored. For more on the characteristics of ratification data see section 5.2.

onmental diplomacy takes places at the regional level, therefore it is only partially interesting to look exclusively at large global agreements (Leinaweaver, 2012). However, regional agreements have, by definition, a different set of potential ratifiers than global treaties. Unfortunately, it has always implicitly been assumed that all the countries that did not ratify an agreement were eligible or potentially capable of ratifying. While this assumption holds for global treaties, it is deceitful when applied to regional agreements. In econometric terms it equates to incorrectly identifying the countries in the risk set. More specifically, it assumes that all existing countries are at risk of ratifying while just a portion of them truly are; the resulting survival estimates are inevitably biased upward.

The data set assembled by Bernauer et al. (2010), and used in most of the studies, seems to be affected by the problem related to regional agreements. There are good reasons to believe that a large fraction of their sample is indeed composed by regional agreements. Bernauer et al. (2010) are aware that some of the agreements could be *de facto* open just to a restricted number of countries. Hence, in appendix they estimate a model exclusively on provenly global agreements, which results in their sample size being halved. The limitations of their data set have already been exposed in section 2.2.1, where we also explain how we tackled the issue by identifying the potential ratifiers of every agreement. The only study that explicitly models regional and global agreements jointly is Leinaweaver (2012). Leinaweaver (2012) controls for the regionality of the treaty by including dummies for the geographic regions of the ratifiers, however this method is not sufficient to deal with the potential bias resulting from the erroneous specification of the risk set. Fortunately, the bias we have just described does not engulf all of the studies, some are unaffected thanks to the more limited sample of treaties or countries that they use. Perrin & Bernauer (2010) and Schulze & Tosun (2013) exclusively focus on agreements negotiated under the UNECE[6]. The analysis is confined to UNECE members because they perceive that non-UNECE nations are not potential ratifiers to these treaties. Schulze (2014) is interested exclusively in the ratification by OECD nations even if the agreements in their samples are open to other countries. Finally, the last paper that does not experience the regionality problem is Yamagata et al. (2017) because they solely study 8 agreements and all of them are global.

In terms of modelling choices the studies differ mostly in how time is defined and in the way they deal with unobserved heterogeneity at the treaty and country levels. The observations are taken annually,

[6]United Nations Economic Commission for Europe

except in Cazals & Sauquet (2015) who track ratification on a daily basis and assume the explanatory variables are constant over the year period. A discrete treatment of time is more frequent. This approach involves expanding the survival data into a binary format in order to fit a binary regression. Then, the baseline hazard is generally parameterised with splines or cubic polynomials. The estimates approximate the ones obtained with a continuous survival model. For continuous specifications of time the preferred modelling choice is Cox PH models (Bernauer et al. 2013a, Schulze 2014, Cazals & Sauquet 2015 and Hugh-Jones et al. 2018). With regards to unobserved heterogeneity, it can lie essentially on two levels, at the country and at the treaty level. It is concerning to notice that most of the studies with large samples account for neither of those (Bernauer et al. 2010, Perrin & Bernauer 2010, Böhmelt et al. 2015, Mohrenberg et al. 2016, Spilker & Koubi 2016); this is a factor that could cast doubts on the consistency of the estimates. There are some exceptions. Cazals & Sauquet (2015) account for unobserved heterogeneity at the country level by including a shared frailty term in a continuous survival model. A shared frailty is the survival analysis equivalent of a country random effect. Yamagata et al. 2017 include treaty dummies. Instead, Schulze (2014) and Hugh-Jones et al. (2018) account for heterogeneity subsisting between treaties by stratifying their models on the basis of the environmental subject of the treaties (Hugh-Jones et al., 2018) or on each individual treaty (Schulze, 2014). The problem with stratification is that it roughly corresponds to modelling each treaty (or group of treaties) separately. This type of solution rules out heterogeneity but has many limitations for large data sets and for limits the ability to produce general inferences. Last but not least, Leinaweaver (2012) and Schulze & Tosun (2013) are the only works that deal with the heterogeneity that could arise both at the country and at the treaty level. These are modelled with random effects in a multilevel structure.

In conclusion, the common goal of these studies is to understand the process of ratification instead of producing a model that describes the ratification of a single treaty. Pooling agreements together does not allow for the same level of detail but greatly increases the size and power of the analysis. The works we presented in this section produced many interesting results and expanded the analysis to a large number of smaller agreements that had been previously ignored. Nonetheless, the benefits of pooling several agreements in a single analysis come together with some methodological complications, the first of which is heterogeneity at the treaty level. Since several treaties are modelled jointly, special attention must be devoted to ensure the consistency of the results. Unfortunately, the treatment of unobserved heterogeneity has globally been unsatisfactory in the literature and the risk of sampling bias has not been properly investigated. To make matter worse, for several studies there is also the suspicion that survival estimates could be biased upward due to an incorrect definition of the risk set. All things considered, these works richly contributed to the findings on ratification, but from a methodological perspective, there is room for improvement especially in large studies of pooled treaties.

Table 3.3: *Pooled survival analysis*

Paper	Sample	Dependent variable	Model
Bernauer et al. (2010)	255 environmental agreements between 1950 and 2000, 180 countries.	Survival data on ratification recorded annually.	Logistic regression for grouped survival data with standard errors clustered on countries. In the appendix the cloglog specification is experimented and a cross-sectional logistic regression is also used to validate the results.
Perrin & Bernauer (2010)	9 Long-Range Transboundary Air Pollution (LRTAP) agreements, 47 Eurasian countries that ratified the 1979 convention. Between 1979 an 2007.	Survival data on ratification recorded annually.	Logistic regression for grouped survival data with clustered robust standard errors (conditional logit with fixed effect for each treaty in robustness checks).
Leinaweaver (2012)	55 environmental agreements (including regional) and 193 countries between 1980 and 2000.	Survival data on ratification recorded annually.	Logit model for survival data with 2 random effects respectively for countries and treaties.
Bernauer et al. (2013a)	286 agreements, 153 countries between 1973 and 2006.	Survival data on ratification recorded annually.	Cox PH model.

Pooled survival analysis (continued)

Paper	Sample	Dependent variable	Model
Schulze & Tosun (2013)	21 agreements negotiated under the UNECE. Ratification of 25 non-EU countries between 1979 and 2010.	Survival data on ratification recorded annually.	Multilevel binary regression for discrete survival model with cross-classified random effects (Cox and logistic regression in appendix).
Schulze (2014)	64 treaties, 21 OECD countries from 1971 to 2003.	Survival data on ratification recorded annually.	Cox PH model with different baseline hazards for each treaty (a shared frailty model is built in robustness checks).
Cazals & Sauquet (2015)	41 environmental agreements ratification by 99 countries from 1976 to 1999.	Survival data on ratification recorded daily.	Cox PH model with frailty term shared at country level.
Böhmelt et al. (2015)	250 agreements, 75 democracies between 1973 and 2002. Data from Bernauer et al. (2010).	Survival data on ratification recorded annually.	Logistic regression for survival data with clustered standard error on country-treaty dyads
Mohrenberg et al. (2016)	219 agreements, 160 countries between 1950 and 2000. Data from Bernauer et al. (2010).	Survival data on ratification recorded annually.	Logistic regression for survival data with standard errors clustered on countries.
Spilker & Koubi (2016)	220 agreements, 162 countries between 1950 and 2000. Data from Bernauer et al. (2010).	Survival data on ratification recorded annually.	Logistic regression for survival data with standard errors clustered on countries.

Pooled survival analysis (continued)

Paper	Sample	Dependent variable	Model
Yamagata et al. (2017)	8 agreements and 166 countries between 1981 and 2006.	Survival data on ratification recorded annually.	Two separate logit regressions (pre- and post-1991) for discrete survival analysis with standard errors clustered on countries. The models include a matrix of weights to account for the interaction between countries (spatial regression).
Hugh-Jones et al. (2018)	126 agreements and 157 countries between 1972 and 2000. Bernauer et al. (2010).	Survival data on ratification recorded annually.	Cox PH model stratified on different areas of regulation, standard errors clustered on countries.

3.2.4 Conclusion

In the second half of this chapter, we traced the evolution of the methodological approach in the ratification literature. At first, empirical studies use mostly a cross-sectional approach with ratification count data. This approach has a series of limitations. For instance, estimates may be influenced by the cut-off date, count data does not allow to study or control for treaty characteristics, and lumping treaties together does not allow to know which agreement has been ratified, just the total number of ratifications. The number of ratification is not a very meaningful measure: does participation in more treaties imply stronger environmental commitments? The number of ratified agreements largely depend on the number of agreements the country can potentially ratify, a factor that has never been accounted for. The fundamental problem of count data is that it does not allow to distinguish how countries differ in their ratification choices for a same agreement. Moreover, this approach does not allow to study how the choice of a country interacts with choices of other countries because cross-sectional studies have no information regarding the timing of ratifications.

Gradually, the approach shifted towards the use of survival models because they allow to study both the occurrence and timing of ratification. We distinguish between studies studying single agreements and the ones studying a sample of treaties. Survival approach tackles most of the shortcomings of previous the methodology. Survival analysis can easily cope with right-censoring. Ratifications can be traced to the treaty and country, therefore treaty and country variables can be studied jointly. And finally, survival analysis allows to study the differences in ratification timing, consequently giving the opportunity to study how ratifications interact with each other. However, survival models for large samples of agreements face methodological complexities which are not always appropriately tackled. Above all, pooled survival models are faced with problems related to unobserved heterogeneity and the identification of potential ratifiers. Unfortunately, both these issues have not been adequately addressed in the literature.

Overall, the methodological differences between count and survival studies make it complicated to compare their findings. For example, models using count data are unable to account jointly for treaty and country characteristics, and differ substantially from survival studies in terms of treaty and country samples, thus they cannot be compared with survival models. Similarly, studies of single agreements are hard to generalise. Their results apply to single treaties and control for very specific aspects relating to the environmental issue treated in the agreement. They cannot be compared to studies of large samples of treaties. As a result, different approaches generally emphasise different variables and questions. Earlier contributions using count data — because of their limitations — study mainly country variables, in particular they emphasise the role of economic development, trade and democracy (e.g. Congleton 1992, Roberts 1996, Frank 1999, Seelarbokus 2014). Later studies employing survival data confirm most of the findings regarding these variables, especially the role played by political variables (e.g. Neumayer 2002a, Bernauer et al. 2013a, Böhmelt et al. 2015). The evidence for economic development and trade is not equally strong. Nevertheless, it is usually found that trade and diplomatic relationships influence the way ratifications interact with each other. In fact, peer nations exhibit interdependence in ratification choices: participation in a treaty by one country prompts participation by its peer nations (e.g. Bernauer et al. 2010, Schulze & Tosun 2013, Yamagata et al. 2017). This sort of analysis is simply not possible in cross-sectional studies because they lack information on the timing of ratification. Pooled survival studies focus mainly on international interactions and occasionally on studying how treaty characteristics affect participation. In essence, the evolution in the approach allowed to answer a progressively larger set of questions.

Chapter 4

A theoretical framework to analyse the determinants of ratification

In the previous chapter we reviewed the empirical studies on the ratification of environmental agreements. We outlined the main conclusions and implications drawn from this body of research. We discussed the data, as well as the methodological choices and approaches that have been used to study ratification. A critical review of the literature would be incomplete if it did not touch on the large existing theoretical literature on the topic of environmental agreements. This branch of economic literature is mainly concerned with applying game theory to the formation, participation and the subsequent compliance with environmental agreements. As of now, there is a substantial lack of communication between the empirical studies of the previous chapter and the theoretical literature discussed in this chapter. Despite being two proximate fields of enquiry, they are mostly working in parallel, with very limited interconnection and reciprocal influence. On one side, the theoretical literature would benefit from empirical evidence to test its assumptions and corroborate its predictions. On the other side, the empirical studies discussed in the previous chapter would benefit from a more rigorous theoretical framework. The goal of this chapter is to introduce the game-theoretical literature on treaty participation and attempt to build a unifying framework for analysing ratification choices.

4.1 Transboundary externalities and international environmental treaties

Most environmental issues are linked to a failure in the first fundamental welfare theorem. Environmental resources share many attributes of a public good: they frequently present missing or incomplete markets and environmental problems often qualify as externalities of production (Kolstad, 2010). All these characteristics lead to an inefficient use of environmental resources and — quite critically — to a systematic under-provision of environmental goods. Under some circumstances, governmental interventions can solve the failures at the source. Typical tools proposed by environmental economics include Pigouvian taxes, subsidies, cap and trade mechanisms or emission standards. If well calibrated, and with sufficient information, these tools could correct the market failure and lead to an efficient use of resources (Kolstad, 2010).

The tragedy of transboundary environmental issues is that a central enforcing power is missing (Perman et al., 2003). Hence, the forms of intervention discussed above lack the central authority needed for implementation of environmental polices over two or more jurisdictions. In the case of domestic environmental problems, the policy maker possesses the authority to allocate property rights, impose taxes and enforce standards (Barrett, 2005). In contrast, environmental policies cannot be enforced beyond national borders in the case of transboundary problems. If domestic agents try to free-ride on environmental policies, the policy maker has the legal power to coerce them into acting accordingly to their policies. However, if foreign nations or entities shirk their obligations, national policy makers have no coercive power to force compliance.

When environmental damages affect multiple nations, the country — or entity — responsible for the damage to the environment does not fully bear the costs associated to their actions (Pearson, 2011). Foreign nations have no way of intervening and, in the case of shared resources, any measure taken unilaterally may be unable to solve the problem or is unlikely to take into account international externalities (Pearson, 2011). Traditional policy tools are ineffective to solve international environmental problems since there is no single dominating power with the authority to enforce environmental policies in all concerned countries. The discrepancy between the scale of the environmental issue and competent political authorities calls for an approach based on cooperation. As of now, international agreements are undoubtedly the primary tool for multilateral cooperation (Perman et al., 2003).

Cooperation has the potential to unite the enforcing power of countries and coordinate domestic actions in such a way as to obtain an efficient use of resources. Through negotiations, countries can agree on mutual and voluntary restraints to be implemented domestically (Finus, 2008). Environmental agreements are the formal embodiment of these restraints and constitute the legal basis for all subsequent governmental action. In principle, environmental agreements can enhance the welfare of nations because they coordinate nations that would otherwise engage unilaterally until the marginal cost equals the national marginal benefit, without taking into account the benefit of their actions on other countries (Barrett, 1994). Essentially, environmental agreements have the potential to internalise international externalities.

Nevertheless, cooperation is not easy and the potential of environmental agreements often fails to materialise. The main challenge faced by environmental agreements is the incentive to free ride (Finus, 2008). International agreements are quintessential voluntary acts: their power is entirely based on the voluntary acceptance of its terms by the individual countries. Non-rivalry in the benefits of environmental agreements means that non-ratifiers can still benefit from the action that other countries take (Marrouch & Chaudhuri, 2015). This forms an incentive to free-ride and capture the benefits of the agreement without bearing its costs. Not only that, since there is no force capable of making a country comply with the agreement, even ratifiers could in principle decide to free-ride on their commitments (Perman et al., 2003). And to make matters worse, transboundary environmental goods are often non-excludable, thus the agreement could be plagued by inefficient levels of provision because countries do not take into account the positive externality of their abatement effort on other nations (Wagner, 2001). All of these elements cast doubts on the incentives to join agreements and on their effectiveness in promoting environmental protection.

In economic theory the challenges faced by environmental agreements have mainly been treated with a game-theoretical approach. These models rest on the duality in the incentives faced by nations (Carraro & Siniscalco, 1993). On the one hand, welfare could be increased by cooperating on environmental issues. On the other hand, the non-rival benefits of the agreement imply strong incentives to free-ride. In transboundary environmental problems the environmental cost of a nation does not depend exclusively on its action but also on what other nations do (Finus, 2008). Hence, countries' decisions are not taken in isolation — they interact in several way. Game theory is the preferred tool used to model the trade-offs and strategic choices faced by nations. The standard framework studies at the same time the level of participation and the environmental commitment to the treaty. In the next section we provide an overview of the economic literature on environmental agreements, highlighting the main implications for the ratification of agreements.

4.2 Theoretical literature on the participation in environmental treaties

A complete review of this vast area of research is beyond the scope of this thesis. The goal here is to provide a general overview of the approaches, predictions, conclusions and topics of the theoretical literature on participation in International Environmental Agreements (IEA). An exhaustive review of the game-theoretical research on formation and participation in environmental agreements is provided by Marrouch & Chaudhuri (2015). Wangler et al. (2013) also offers a good section on the political economy side of treaty participation. For a broader introduction to the area, Wagner (2001) provides a thorough overview of the main issues surrounding treaty formation and participation in a non-cooperative setting. A more detailed treatment of the main challenges and assumptions underpinning the game-theoretical analysis of multilateral environmental agreements can be found in Finus (2008), who also integrates the standard membership game with payoffs generated by an Integrated Assessment Model (IAM)[1].

In general, participation in environmental agreements is modelled in two different ways. The first is to use a two-stage game where the first stage corresponds to the signature/ratification and the second to the abatement/implementation phase. The second type of approach involves dynamic membership where countries can choose their membership status in every time period. The two-stage game is the predominant approach in the literature. Differences among games are mainly based on whether the nations are assumed to be homogeneous (with

[1]IAMs are computable general equilibrium (CGE) models that combine both economic and geophysical modelling. IAMs are very common in the analysis of climate change; some examples of IAMs of climate change include the RICE model by Nordhaus & Yang (1996) or the WITCH (Bosetti et al., 2006) model developed by the Fondazione Eni Enrico Mattei (FEEM) and Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC).

symmetric pay-offs) or heterogeneous; or whether the abatement decisions are taken simultaneously or first by the ratifiers. Games also differ in whether full information is assumed or on how uncertainty is modelled. The remainder of the section presents a typical two-stage game that is used as reference for later discussions. Then, we present the main conclusions of the theoretical studies on environmental agreements. In the last part of the section we expound on recent developments and illustrate how public choice theories conciliate with the classic framework of analysis. From this literature different implications are drawn on the impact of domestic interest groups and the determinants of ratification.

4.2.1 Set-up of a typical game

In this section we present a typical game of ratification similar to the one in Carraro & Siniscalco (1993). The notation and structure of the model are derived from Marrouch & Chaudhuri (2015). We advise the reader to refer to the source for a more extensive discussion of alternative assumptions and structures of environmental agreement participation games.

Environmental agreement participation game

Consider the case of the emissions of a hypothetical pollutant generated as by-product of industrial production. The pollutant is regarded as a pure public bad. Let e_i be the emissions of pollutant from country i. The total emissions, E, for a set of N countries is equal to $E = \sum_{i=1}^{N} e_i$. The pollutant has a negative effect on a country's welfare, which is summarised by a damage function $D_i(E)$. $D_i(E)$ is an increasing function linking global emissions E with the damage to a country i. However, emissions are also associated with some benefits for the emitting country. The function $B_i(e_i)$ represents the benefits of emissions for country i associated with industrial production. In this set-up we consider symmetric countries, hence the benefit and damage functions are identical for all nations. The welfare of a country i corresponds to the reduced-form pay-off function:

$$W_i = B_i(e_i) - D_i(E) \qquad \forall i \in N \tag{4.2.1}$$

Both linear and convex functions are commonly used to model the damage and benefit functions. The exact curvature properties have implications for the conclusions of the model. For instance, when both the damage and benefit functions are linear, the emission choice for the country is binary: either it pollutes or it abates. If one or both of the functions are non-linear, the level of emissions is defined over a continuous interval and ultimately depends on the parameters of the model. Given the sensibility of predictions, some empirical guidance would be helpful in the parametrisation of theoretical models.

The typical 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. The structure of the game is common knowledge, meaning that countries have complete information of other players' strategy space and payoff functions. The game is solved by backward induction. We denote the subset of ratifying countries in the first stage as $R \subset N$. In the second stage the ratifiers and non-ratifiers simultaneously choose their emission levels by taking the strategies of the other players as given. In equilibrium, the welfare of the ratifiers and non-ratifiers is defined respectively as W_r^* and W_{nr}^* in correspondence of the optimal emission levels.

Whether or not a country decides to join the coalition of ratifiers in the agreement depends on whether it is beneficial to do so. Hence, the treaty needs to be self-enforcing because of the absence of a central authority capable of enforcing the agreement. The self-enforcement of an agreement for non-cooperating countries is normally assumed to rely on the cartel stability criterion identified by D'Aspremont et al. (1983), which implies that a self-enforcing agreement yields a stable coalition if it is externally and internally stable. A coalition is internally stable if it is less beneficial for a member to leave the coalition rather than unilaterally maximising its welfare; that is to say, for all $i \in R$, $W_r^*(r) \geq W_{nr}^*(r-1)$ where r is the number of ratifying countries and nr of non ratifying countries. The coalition is externally stable if it is less beneficial for a non-member to join the coalition instead of unilaterally maximising its welfare; that is to say, $W_{nr}^*(r) \geq W_r^*(r+1)$ for all $i \notin R$.

A stable coalition can be achieved with this set-up, but the size of the coalition — and consequentially the number of ratifiers — is rather small. Ultimately, the exact value of r depends on the curvature of the benefit and damage functions. When both functions are linear two outcomes are possible: either a grand coalition or no coalition at all. The first outcome is achievable only with a shallow agreement entailing abatement levels no higher than the unilateral non-cooperative equilibrium (Barrett, 1994). According to Carraro & Siniscalco (1993), when the benefit function is quadratic and the damage function is linear, the best response function is orthogonal and the largest stable number of parties to the agreement is 3. When the marginal benefit of emission is constant but the damage function is quadratic, a stable coalition of two countries is achievable. Finally, when both functions are quadratic, the largest stable coalition comprises only one country. As it is evident from these examples, environmental agreement participation games generally predict very dire ratification and abatement scenarios.

More complex games

The game presented in this section represents the simplest case of a static cooperation problem. More complex types of games, with different assumptions and structures, imply varying levels of participation.

For example, dynamic games allow choices to be protracted in time instead of being a one-off simultaneous decision. In dynamic games, countries can decide at each period whether they want to participate in the agreement and/or how much to abate. This type of games supports sequential ratification decisions. Calvo & Rubio (2013) review a large number of applications for this type of modelling. The games can also be made more realistic by defining heterogeneous countries. Countries often have different incentives to participate, hence symmetry in the pay-offs is a simplifying assumption. The first paper considering heterogeneous countries is by Hoel (1992). In Hoel (1992) every country has a different (constant) marginal benefit of abatement, while the marginal cost is assumed to be equal for all countries. Heterogeneity does not alter the pessimistic conclusions on treaty participation. In fact, Hoel (1992) finds that the largest stable coalition that a treaty can sustain has only two players. Nevertheless, evidence is mixed in the case of heterogeneous countries; recent works have shown that strong asymmetric distributions in the benefits and costs of a treaty may induce higher gains from cooperation and could sustain the grand coalition if transfers are allowed (Finus & McGinty, 2015).

Another branch of the literature developed games that do not assume perfect information. Uncertainty mainly regards the abatement performance of foreign nations as well as the benefits of the agreement and how they are distributed (e.g. Na & Shin 1998 or Kolstad & Ulph 2011). Generally, the participation level increases compared to the full information case, however some types of uncertainty — such as uncertainty over environmental damages or a country's commitment — increase shirking risks and lead to even more pessimistic conclusions.

A fundamental assumption in game theory regards how country decisions are taken, and consequentially, the criteria for the stability of coalitions. Marrouch & Chaudhuri (2015) distinguish mainly three criteria: *non-cooperative*, *cooperative* and *farsighted stability.* In non-cooperative games a country that decides to leave the coalition does not affect the participation of the other members of the coalition because every nation takes decisions based solely on its self-interest. Conversely, cooperative games maximise the welfare of the coalition and imply that the participation of all the countries is necessary for a stable coalition. If a country decides to defect, the entire coalition shatters in response (Marrouch & Chaudhuri, 2015). Between these two extremes, farsighted stability assumes that a country behaves non-cooperatively, but the country also takes into consideration the impact of its participation status on the participation of other countries and accounts for all possible chain reactions (Finus, 2008). The implications for the stability and size of coalitions vary considerably depending on how decisions are taken. For example, Diamantoudi & Sartzetakis (2006) find that under farsighted stability, stable coalitions are attained with larger sizes than under classic non-cooperative assumption (e.g. Barrett 1994). This result is confirmed by Biancardi & Villani (2010) in a two-stage game, which also shows that stronger environmental awareness can sustain larger coalitions.

4.2.2 Emerging conclusions

Participation vs depth

To summarise the main results of participation games, Barrett (1994) states 3 stylised points about the effectiveness of environmental agreements and the level of participation:

- Agreements codify commitments that countries would undertake unilaterally even without the agreement;
- when the number of participants to the agreement is large, the agreement brings few obligations and implies a low abatement effort;
- 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 rates of ratification should be achieved only when the commitment level is low, whereas stringent agreements should hardly receive any ratification. Later works have corroborated the trade-off at the basis of the paradox, with some improvement in the views expressed in the latest contributions (Finus et al., 2017).

The pessimistic conclusions originate from the theoretical framework adopted. Transboundary environmental issues are analysed with games framed as prisoner's dilemmas, where the Nash equilibrium lies in a non-cooperative solution. The only case in which the parties decide to undertake positive abatement commitments beyond their unilateral levels is when they decide to cooperate. However, cooperation leads to unstable coalitions. Very much like cartels, members to the agreement have the incentive to free-ride, hence game theory ultimately predicts that the agreement does not deliver any environmental gain beyond the non-cooperative solution.

The only exception to this outcome is when agreements are *self-enforcing* — that is to say, the incentive structure is such as to induce a stable cooperating coalition. But these cases are traditionally deemed rare and not occurring for the most pressing environmental issues (Barrett, 2008). According to the literature, one of the most effective ways of building self-enforcing agreements is to include penalties for defecting nations (Barrett & Stavins, 2003). Nonetheless, this mechanism raises a series of issues. In the first place, parties need to be able to monitor the activity of other nations because they have an incentive to overestimate their abatement action in a situation of imperfect information. Furthermore, countries cannot be forced to pay their fines or keep their promises because of the absence of an enforcing authority. Finally, penalties increase the cost of participating in the agreement; and the more stringent the agreement, the less likely it is to attract participants (Perman et al., 2003). In essence, this framework of analysis depicts an impossible impasse based on a trade-off between depth of cooperation and breadth of participation in the agreement (Bernauer et al., 2013a). Perman et al. (2003, p.310) summarise it as follows: "The larger are the potential gains to cooperation, the greater are the benefits of free-riding and so the larger are the incentives to defect. But the larger are the incentives to defect, the smaller will be the number of signatories".

Mitigating factors

Subsequent works introduced additional mechanisms that mitigate in part the pessimistic predictions of game-theoretical models. First, if ratifiers offer side payments other countries have a stronger incentive to join (Barrett & Stavins, 2003). Countries that do not ratify the environmental agreement renounce to side payments associated to the agreement. The missed opportunity on side payments acts as a negative externality generated by the ratifiers, parallel to the positive externality deriving from pollution abatement (Wagner, 2001). This type of transfers is quite common in reality, in fact a large number of environmental agreement include some form of support to developing nations. There is also empirical evidence that this type of mechanisms tangibly boost participation (von Stein 2008, Bernauer et al. 2013b). From a theoretical perspective, a number of contributions have shown that side payments modify the conclusions on the size and stability of coalitions. For example, Carraro & Siniscalco (1993) expand their model to include side payments among members of the agreement. They demonstrate that, even under non-cooperative assumption, side payments can increase participation in the agreement. Side payments are found to be particularly effective when heterogeneous countries are considered (Barrett 2001; Fuentes-Albero & Rubio 2010). Carraro & Siniscalco (1993) suggest that side payments do not need to be strictly monetary. For example they could take the form of technological transfers or concessions to the country. Nevertheless, in order to induce non-participants to ratify it is important that ratifiers' commitment to remain in the coalition is credible.

Another mitigating mechanism is to link environmental agreements to other forms of cooperation. For example, it is often found that free-riding incentives are greatly reduced if the environmental agreement includes some form of trade restriction (Barrett, 1997). However, trade sanctions are not the only possible form of linkage. Communication and parallel negotiations between environmental agreements also contribute to higher participation levels (Carraro & Siniscalco 1998, Bloch & Gomes 2006). Biancardi & Villani (2015) develop a model of treaty participation with two groups of heterogeneous countries that also have the possibility of cooperating in environmental R&D. Ratification of the agreement creates a positive externality for the coordination of research. In the end, Biancardi & Villani (2015) find that participation in environmental agreements increases compared to the model without linkage to environmental research. Furthermore, environmental agreements could be linked with other forms of cooperation through "reputation effects". Hoel & Schneider (1997) are among the few papers modelling this form of interaction. Hoel & Schneider (1997) define a reputational cost for non-ratifiers that increases with the number of participants in the agreement. Reputational costs augment participation by offsetting the free-ride incentives. The connection between treaties and other forms of cooperation has been explored in more detail by the empirical literature on ratification (e.g. Neumayer 2002b, Bernauer et al. 2010, Schneider & Urpelainen 2013, Yamagata et al. 2013)[2].

[2]For more on the treatment of this subject in the empirical literature see section 3.1.4

Thirdly, depending on how games are set, the game-theoretical approach could still predict more optimistic scenarios. For example, if, instead of framing the problem as a one-off decision, countries — through repeated games — are allowed to start participating in different periods, outcomes are generally more encouraging. In fact, higher participation rates are attained especially when communication is allowed (Marrouch & Chaudhuri, 2015). For instance, Wagner (2016) elaborates a model that is casted as a repeated game with infinite horizon. In every stage the countries can decide either to ratify or to abstain from ratifying. Unlike other models of treaty participation Wagner (2016) assumes that the payoff of countries increases over time. As a result of this assumption, all nations are bound to ratify the treaty on the long-run. Moreover, the model accommodates interactions among country ratifications which can either be positive (complements) or negative (substitute). Since the ratification outcome is guaranteed by the core assumptions, the model essentially describes the delay in ratification, which depends on whether there is complementarity or substitutability in ratifications. Eventually all countries will ratify, and the ratification order will reflect the relative benefits of cooperation.

Finally, specific design features of the treaty could boost participation and commitment under the agreement. For instance, Carraro et al. (2009) and Rubio & Casino (2005) find that treaties with minimum participation rules — that is to say a minimum number of ratifiers before the agreement enters into force — lead to large stable coalitions. It is generally found that a minimum participation rule leads to coalitions of size corresponding to the minimum number of countries required for the entry into force of the agreement. This result derives from the fact that any coalition smaller than the minimum induces unilateral abatement levels which are less desirable for all countries. The models of Carraro et al. (2009) and Rubio & Casino (2005) are based on simplifying assumptions; for example, they assume homogeneous countries and complete information. A stable coalition is no longer sustainable when uncertainties over the benefits of abatement are taken into account (Wagner, 2001). To a lesser extent, other treaty features receive treatment too. For example, Karp & Zhao (2010) explore the effects of agreements with penalties and permit trading schemes on the degree of participation and effectiveness of the treaty. They find that an agreement with trading schemes entails lower levels of participation but higher abatement commitments.

4.2.3 Public choice theory and environmental agreements

We have presented the classic game-theoretical model used to analyse participation in environmental agreement. This model produces dire conclusions for the attractiveness and usefulness of treaties. To a certain degree, the dire conclusions are mitigated by elements such as side payments, linkage of issues, or specific treaty features and modelling choices. This part of the chapter explores how public choice theory interacts with the classic model and investigates the influence of domestic agents in the political process of ratification.

Public choice perspective on environmental policies

Up to this point the models presented in this chapter portray policy makers as benevolent tyrants that act strategically to maximise the welfare of their countries. Public choice theory breaks this assumption and states that policy makers are motivated by self-interest. Under this assumption, individual incentives can influence the outcome of governmental policies. Buchanan & Tullock (1975) is one of the first studies explaining the selection of environmental policy instruments based on the interests of domestic agents. Their work spurred a vast research work that solidified the understanding of the political processes involved in governmental actions.

Pressure groups appear in Damania (1999), who builds a theoretical model of political lobbying to explain the selection of environmental policy instruments. In his model emission taxes are proposed by parties that represent environmental pressure groups. Most of the time environmental pressure groups do not have sufficient political strength, so less costly environmental policies are adopted — such as emission standards. Even when environmental taxes or charges are introduced, they are not strong enough to entail sufficient reduction in emissions because of the strong industrial lobbying influence. Similarly, Dijkstra (1998) uses a game-theoretical approach to explore the choice between two environmental policy instruments (market instruments and direct regulation) when government decisions are open to the influence of industrial pressure groups. They conclude that market instruments, such as tradeable emission caps, are implemented less often because of the impact of lobbying activity. These results are echoed in a separate paper on market-based policies by Kollmann & Schneider (2010). The work of Dijkstra (1998) is expanded by Beard et al. (2007) in a two-stage game of political lobbying for environmental policies in which government has imperfect monitoring capacities. And in a similar fashion, Glachant (2008) builds a model in which the government selects between three environmental policy instruments (emission standard, tax on emission, tradeable emission permits) under the influence of pressure groups representing polluting industries. The model implies that tradeable permits dominate the other policy instruments because free allocation of trading permits makes it the preferable outcome for lobbying industries. The equilibrium does not represent a social optimum because instruments such as emission taxes generate a financial influx to the government while free allocation only fixes an emission cap.

In summary, public choice theory widely recognises that the interest of domestic interest groups may affect the formation and implementation of environmental policies. However, study of the implications of domestic dynamics for international policies — in particular the participation in environmental agreements — is a recent development in the literature. The existing work mainly focuses on the impact of elections over the choice of environmental policies. For example, Buchholz et al. (2005) investigate how participation in environmental agreements is affected by government's electoral incentives. In a similar paper, Roelfsma (2007) builds a model articulating the response of the level of environmental commitment to the preferences of electors. The author argues that when the preferences of electors are taken into account, the abatement is higher than the non-cooperative level predicted by conventional game-theoretical approach.

The use of median voter models is another method to incorporate electoral incentives in governments' choices. The median voter theorem states that a government needs to meet the preferences of the median voter in order to get elected. This idea can be used to examine how ratification decisions are influenced by the preferences of electors and other domestic actors. These models are usually framed in two stages. The first one corresponds to the election of the government, the second to the negotiation (and ratification) of the agreement. It is generally concluded that electors choose governments with different environmental preferences from their own (Roelfsma 2007, Hattori 2010); government's *penchant* for environmental protection depends on the specific design of the model and on the fundamental assumption of whether countries behave cooperatively or non-cooperatively. According to these models, when electors have strong preferences for environmental protection, participation in agreements tends to be very likely. If environmental preferences are strong enough, the effect manages to overturn the pessimistic predictions of classic game-theoretical literature on the participation and effectiveness of environmental agreements (Wangler et al., 2013). This is in line with the scenario described by Kirchgässner & Schneider (2003) which describes how the increasing demand for environmental protection led to the formulation of environmental policies that were initially opposed by industrial lobbies. Thus, the indirect pressure of voters acts as a competing force of lobbying of special interest groups.

In a representative democracy, the outcome of government's decisions is not solely based on electoral preferences. Very often, interests of strong domestic groups are able to influence political outcomes. In a seminal contribution, Grossman & Helpman (1994) develop a model in which interest groups and elector's preferences affect trade policies; a similar framework is also applied to free-trade agreements (Grossman & Helpman, 1996) and trade policies Grossman & Helpman (1995). Policy makers maximise a political support function that encompasses both electoral support and contributions by interest groups[3]. This has implications also for ratification decisions. Policy makers might take into consideration the contributions of industrial and environmental lobbies when deciding on their participation in environmental agreements. In reference to this idea, Fredriksson (1997) and Aidt (2010) explore the influence of interest groups on environmental tax rates. Their models predict a negative effect of industrial lobbying on environmental taxes. These examples describe the influence of interest groups on general environmental polices, but in addition to these efforts, a growing body of research attempted in recent years to merge the effects of domestic interest groups with the theory on participation in international environmental agreements. This body of research is directly pertinent to our research questions; it will be reviewed in detail in the next paragraph.

Interest groups in models of treaty participation

In essence, public choice theory promotes an atomistic view of policy intervention. 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 "environ-

[3]Contributions from lobby groups are not necessarily monetary; e.g. media coverage, logistic support, personal contacts or information for policy making.

mental policy selection". In recent years this effort has been extended from environmental policies to environmental agreement. Research focuses on embedding the effects of lobbying practices and electoral incentives into the classic game-theoretical framework of treaty participation. These models respond to the need of accommodating a more realistic political process within the classic framework of analysis (Carraro & Siniscalco, 1998).

According to Putnam (1988) and Barrett (1998), ratification is the outcome of a two-stage game: the first played internationally by national representatives during the negotiation phase of the treaty, the second domestically by the political institutions and domestic stakeholders. A realistic model of treaty formation and participation needs to consider the domestic dynamics that could impinge on the willingness of countries to join environmental agreements. At the moment, there is a growing effort to assimilate the leanings of public choice theory into the classic framework of analysis. This type of work is directly relevant to our research questions and formulates interesting predictions about the role and impact of domestic interest groups on treaty participation.

Haffoudhi (2005) is one of the earliest contributions lying at the intersection of public choice theory and treaty participation literature. Haffoudhi (2005) develops a model in which environmental and industrial lobbies influence the ratification of environmental agreements through political support to politicians. The political interactions are grafted on a classic non-cooperative two-stage game of environmental agreement participation, with a one-off participation choice and simultaneous abatement decision, identical to the one presented at the beginning of this chapter. In Haffoudhi (2005), the citizens of every country are organised in two groups: environmental and industrial groups. The environmental group benefits from an increase in the global abatement level and is harmed if the abatement level of the country is lower than the environmental equilibrium level. In contrast, the industrial group would prefer the abatement level to be as low as possible in the country. The political support offered from environmental and industrial groups depends on the welfare gains derived from government's actions. In this model, rather than opting for the social best, politicians maximise a function of political support. Countries deciding to join the environmental agreement maximise the coalition's political support function while non-ratifiers maximise unilaterally their political support function. Ultimately, governments choose to participate in the agreement and choose the abatement level in such a way as to maximise the support from the two domestic groups. The precise outcome depends on the exact specification of the support function and payoffs for the lobby groups. Haffoudhi (2005) specifies payoff functions similar to the ones in Carraro & Siniscalco (1993) and assumes that the political support function is linearly additive. In the end, a stable coalition is achievable and the participation of a country depends on the relative strength of the two groups.

Habla & Winkler (2013) also encompass domestic interest groups. Their game analyses the choice of countries to join a common permit emission scheme in a first stage and choose the level of emission allowances in a second stage. This model has the same structure of a classic two-stage game of environmental treaty participation, but in this game the agreement relates specifically to the institution of a common market for emission permits. The game has some special features. Firstly, it is played by only two countries. The tradeable permit scheme is only formed if both countries decide to participate. Secondly, groups of industrial lobbies can affect both the "ratification" phase and the phase in which the number of emission allowances is chosen. Industrial interest groups are not assumed to be unitary groups but a multitude of lobbies. Environmental lobbies are not explicitly modelled, however demand for environmental protection is channelled through electoral support to politicians. As a result, policy-makers balance two conflicting incentives. On the one hand, environmental protection increases the welfare of voters. On the other hand, favouring the interest of industrial lobbies could grant easier re-election thanks to their support and financial backing (funding campaign, information or even bribes). In the end, Habla & Winkler (2013) conclude that it is the aggregate strength of industrial lobbies that affects participation to the scheme, rather than the distribution of power among lobby groups. Interestingly, they also find that if the influence of a single lobby group greatly increases, the interest of that lobby is less likely to be attended in both countries. Depending on the parametrisation of the electoral preferences in this model, the effect of the lobbies could be reduced. That is to say, if the preferences of voters are strongly in favour of participation in the treaty, the policy-maker would find it advantageous to tap into the electoral benefits rather than favouring industrial lobbies.

Hagen et al. (2016) study participation in environmental agreements and abatement decisions when environmental and industrial lobbies influence decisions of policy-makers. Their model does not treat electoral dynamics, it just focuses on rival contributions from the two lobby groups. The contribution of lobbies to the policy-makers represents their willingness to pay in order to see their desired policy adopted. Again, an equilibrium ratification and abatement level is derived from a two-stage treaty participation game in which the decisions of countries take into account both the benefits of abatement and the contributions of environmental and industrial lobbies. Industrial groups offer contributions hoping to decrease abatement levels while environmental groups wish to increase abatement levels. The framework of the analysis is very similar to that of Haffoudhi (2005). However, unlike Haffoudhi (2005) and Habla & Winkler (2013), they consider heterogeneous countries. Furthermore, the support of lobby groups is exerted with a delay in time. Before ratification and abatement decisions are taken, environmental and industrial lobbies announce their intended contributions on the basis of the expected abatement level. Then, after the ratification and abatement decisions are taken, lobby payoffs are determined and contributions are paid according to the original announcements.

Abatement levels are decided simultaneously by ratifiers and non ratifiers in the second stage of the game. Hagen et al. (2016) conclude that the abatement level of ratifiers and non-ratifiers is influenced by the announced contributions of environmental and industrial lobbies in the expected direction. Higher environmental contributions lead to higher abatement, while higher industrial contributions lead to lower abatement. The effect of environmental lobby groups in a ratifying country also increases abatement in other ratifying nations because ratifiers are assumed to behave cooperatively. Regarding the participation levels in the agreement, lobbying has ambiguous effects for the stability of coalitions. Industrial lobbying lowers the ratification incentives of other countries, but has no clear effect on the country in which the lobby is based. On the contrary, environmental lobbying increases the likelihood of a country to join the coalition, but reduces the likelihood of other nations to ratify. Environmental lobbying is associated with higher participation because it mitigates the costs of higher abatement levels that come with treaty membership. The "spillover" effect of lobbying offshoots from the joint maximisation process of ratifiers (cooperative behaviour), which implies that an increase in the abatement in one of the ratifiers also requires an increase in abatement levels in all other ratifiers. All of this entails higher abatement costs that dissuade less ambitious countries from joining the agreement. In the end, the ambiguous effect of lobbying prevents the determination of a stable coalition size.

The work by Hagen et al. (2016) shows that domestic interest groups may have a strong impact on the size, depth and stability of international coalitions. They further show that environmental lobbying is able to positively influence a country's propensity to ratify an agreement. The effect of industrial lobbying results on lower abatement levels, but has an ambiguous effect on ratification. Conversely, environmental lobbying increases the likelihood of joining the treaty, but has an ambiguous effect on the level of abatement.

In Marchiori et al. (2017) the structure of the game is nearly identical to that in Hagen et al. (2016). Countries have two opposing interest groups with different welfare functions which determine their willingness to contribute. The main difference revolves around the way contributions are announced and paid. Marchiori et al. (2017) distinguish three phases: *i*) in the first phase the lobby groups announce their intended contributions; *ii*) given these contributions the policy makers in every country simultaneously decide their abatement levels; *iii*) finally, lobby groups make contributions based on the choices of the policy makers. The ratification decision is derived by backward induction after the abatement level is set. The influence of lobbies is assumed to depend on the level of organisation of the lobby and the preference for "contributions" of the policy maker. Paradoxically, they find that in correspondence of strong preferences for contributions a country is more likely to join the agreement when industrial lobbies are strong or environmental lobbies are weak. The reason behind this finding is that higher abatement levels will be expected if a country joins the agreement. As a result, industrial lobbies will be propense to make larger contributions to avoid high abatement levels in the second stage. Conversely, strong environmental lobbies will make larger contributions when the treaty is not ratified in order to limit the environmental damage. Hence, policy makers maximise contributions by joining the agreement when industrial lobbying are strong or when environmental lobbies are weak. However, if contribution announcements occur before the ratification decisions is taken (phase *i* and *ii* are inverted), the results return to normal because ratification can no longer be used by the government to extract maximum returns. In this case, government ratifies when the environmental lobby is strong or the industrial lobby is weak.

A final contribution in this area of research comes from Köke & Lange (2017). Unlike in previous works, Köke & Lange (2017) more realistically separate the negotiation (and signature) from the ratification (and entry into force) of agreements. They consider different players at the national level and recognise that the entities that negotiate and sign the agreement are different from the ones that ultimately ratify and determine the entry into force of the agreement. Following Putnam (1988) framework, participation to environmental agreement is seen as the outcome of a two-levels game in which country's representatives have to negotiate an agreement with international players but also have to satisfy the domestic actors responsible for ratification. By taking the classic participation game as a reference, Köke & Lange (2017) introduce two intermediate stages in which negotiators endogenously agree on a minimum participation rule, then domestic legislative bodies choose whether to ratify the agreement. As a consequence, a treaty could be agreed by a coalition of countries, but then some countries in the coalition might subsequently fail to ratify. Compared to the traditional framework, this model provides a more realistic representation of the ratification process.

The payoffs are derived from a welfare function similar to that in equation 4.2.1, except that the benefit function discerns two separate domestic actors: the negotiator (government) and the ratifier (legislative body). The negotiator and the ratifier have different preference functions toward the agreement. Furthermore, the negotiator's knowledge of the preferences of the ratifier are subject to uncertainty. In general, this framework of analysis leads to more optimistic conclusions over participation levels in the agreement. Since countries have the possibility of not ratifying, the number of countries joining the coalition in the first stage is much larger, which in turn leads to higher payoffs in case of ratification. The analysis also indicates that negotiators will try to reduce the abatement commitments implied by the agreement in order to make ratification less costly and more likely. The authors evaluate the impact of minimum ratification clauses on participation levels when ratification is uncertain. They find that the impact of participation rules is different from the classic scenario. With lower levels of uncertainty in the preferences of domestic ratifiers, the clause enlarges the stable coalition, whereas high uncertainty cancels the effect of a minimum participation clause. Finally, Köke & Lange (2017) find that participation in environmental agreements increases when there is uncertainty over ratification.

4.3 Framework of the empirical analysis

So far, we have presented the theoretical literature surrounding participation in environmental agreements. We also explored how public choice theories integrate with this body of literature, producing interesting conclusions on the influence of domestic interest groups. In this last section, we pull together all the elements discussed so far in order to build a framework for the empirical study of treaty participation, and formulate a set of hypotheses that will be tested in the course of our analysis.

4.3.1 Studying the determinants of treaty participation

The prevailing theoretical framework is the following. Nations are seen as unitary actors that maximise domestic social welfare. Environmental issues affecting a group of countries could be solved by the negotiation and participation in international environmental agreements. However, countries also have an incentive to free-ride on environmental agreements to get the environmental benefits without bearing the costs associated with the treaty (Pearson, 2011). This dynamic has been treated by several economic models, mostly using game-theoretical approaches, with the aim of predicting the optimal abatement and participation levels. The conclusions are generally pessimistic on the capacity to solve environmental problems beyond the non-cooperation level (Wangler et al., 2013). This outlook originates from the core assumptions of the models, in particular how free-riding incentives are defined and whether or not compensating mechanisms are included.

The case for empirical evidence

According to classic models, environmental treaties are ineffective and do not induce abatement levels higher than what would be achieved unilaterally because of the strong free-ride incentives (Barrett 1994, Carraro & Siniscalco 1993). Large coalitions can only be achieved with low abatement targets that fall short of the social optimum (Finus, 2008). The prevalent conclusions seem to be at odds with what is observed for many treaties. It is not uncommon to observe participation levels that are higher than what would be expected by theoretical results. However, it is hard to control for the "depth" of the agreement, hence it is often unclear whether these agreements involve abatement levels higher than the non-cooperative equilibrium. Some papers attempted specifically to tackle the thorny question of environmental commitments; the results are mixed. For example Bratberg et al. (2005) find a positive effect on abatement levels compared to the non-cooperative solution, but Ringquist & Kostadinova (1985) does not. Other papers focused on the level of participation and found that the trade-off between the strictness of the agreement and the number of members is not inevitable. According to Bernauer et al. (2013b) and von Stein (2008), some design features of environmental agreements could promote participation and simultaneously induce tighter obligations for its members.

Theoretical models also depict strong free-ride incentives on abatement commitments. However, non-compliance with the agreement is rarely observed, penalties or sanctions have seldomly been applied, and free riding on commitments is generally considered less problematic than what is postulated by game-theoretical models (Wagner, 2001). In many countries ratification makes the content of the agreement nationally binding because the text of the agreement acquires the same value of domestic laws. Although cheating on abatement commitments is still possible, it should corresponds to the same type of cheating that a country experiences for national policies. All of this may suggest some discrepancies between the theoretical predictions and observed facts. Nevertheless, the limited amount of empirical evidence does not allow to draw final conclusions.

A drawback of the traditional game-theoretical approach is that it is often hard to apply to real agreements. As a first issue, the payoffs of the games are hard to determine in reality. The most realistic method is to use integrated assessment models (IAM) to generate payoffs for the participation games (e.g. Tol 2001, Carraro et al. 2006 or Bosetti et al. 2013). However, IAMs model exclusively a handful of environmental issues. A climate change IAM cannot be applied in games treating other types of environmental problems. Despite these advanced methodologies, theoretical models tend to over-simplify the incentives faced by countries, particularly non-material factors which are the hardest to incorporate in the current framework (Finus, 2008). For example, a country's decision to join an agreement could depend on strong peer effects, gains in diplomatic reputation, or the coordinating role of international institutions [4], ethical considerations of fairness and equity, or the interest for the well-being of future generations (Finus, 2008). Some of these are often important factors in political science literature which have found consistent empirical support (e.g. Frank 1999, Recchia 2002, Neumayer 2002a, Schneider & Urpelainen 2013, Schulze & Tosun 2013, Hugh-Jones et al. 2018).

From this point of view, the premise of the classic model does not

[4] International organisations are widely acknowledged to have fostered international cooperation (Roberts et al., 2004). These organisations often initiate, promote or endorse environmental agreements. A large share of the agreements in our data set are agreed under the guardianship of the European Union, the United Nations or one of UN's specialised offices (See Appendix B).

seem to entirely fit the facts and overlooks important factors that could underpin national decisions. For analytical ease, treaty participation games rely on simplifying assumptions. Assumptions which are often embraced without a thorough understanding of their impact on the final conclusions of the models. For example, nearly all studies assume no distinction between the formation of the agreement (signature) and the adhesion to the treaty (ratification) (Köke & Lange, 2017). Moreover, many games — such as the one presented at the beginning of this chapter — assume that ratifications are a one-off simultaneous decision. From a strategic perspective the incentives change when sequential or repeated ratification choices are allowed (Marrouch & Chaudhuri, 2015). Often studies are framed in a full-information setting, while in reality uncertainty clouds environmental problems and policies. Asymmetries in incentives are often ignored and constant marginal benefit of abatement are frequently used (Perman et al., 2003). Furthermore, fundamental assumptions on how decisions are made can significantly alter the outcome of the game (e.g. cooperative vs non-cooperative equilibrium). All this makes it hard to apply game theory to real environmental treaties.

It has been argued by Finus (2008) that these simplifications are useful to derive workable models of environmental agreements. However, the accuracy of the core assumptions is rarely put to a serious test. To make matters worse, there is a substantial lack of empirical evidence verifying whether the structure and implications of the game-theoretical approach correspond to a realistic model of environmental treaties. Our work attempts to contribute in this direction. The need for empirical analysis has been stressed in previous works (Carraro & Siniscalco 1998, Finus 2008). Empirical analysis allows one to assess the functionality of the models and verify how these models translate on real data. To that, empirical evidence is lacking mainly because several of the variables involved are hard to quantify. The free-ride incentives faced by countries, the strictness of the agreement, or the negotiation position during bargaining phases are all concepts that are hard to measure and for which data is not readily available. Taking into account the limitations in data availability, we now expound on how our empirical analysis fits within the theoretical framework of IEA participation games. This framework of analysis is then used to formulate hypotheses on the effect of key variables of interest.

A framework for analysing ratification

Game theory is used to study the conditions necessary for the formation of agreements and subsequently the equilibrium level of abatement. In many cases, empirical analysis lacks a proper counterfactual to carry an equivalent analysis. For example, we do not observe the potential agreements that never came into existence, and we cannot derive the unilateral abatement levels in the case of coalition members. It is complicated to keep track of negotiations and equally complex to observe what environmental issues have been the object of negotiations and which instead have been excluded. In this respect empirical analysis has limited scope for additional insight, because studies of environmental agreements can only evaluate agreements that have taken shape. Even for existing agreements, the formation process is hard to follow and the characteristics of the treaty — such as its stringency or implied abatement levels — remain hard to qualify and compare across treaties. Yet, despite the limitations in measurability and data availability, empirical analysis is still able to test theoretical predictions and generate precious insights that could inform a better understanding of the dynamics at play.

In this thesis we mainly focus on the determinants of participation in environmental agreements. As mentioned above, we only observe agreements that already took shape. Hence, we specifically answer to the question: *Given that an agreement has been agreed, what motivates participation?* This type of analysis necessarily overlooks the process of formation of the agreement, but it still able to tackle many of the questions raised by classic game-theoretical models on the level of participation in environmental agreements.

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. Hence, only ratifiers are interpreted as participants in the agreement. We take the model described in Köke & Lange (2017) as conceptual reference. Their 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[5]; in the third stage, countries implement their environmental policies. The goal of our study is to evaluate the ratification choice of countries 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

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

Figure 4.1: *A model of environmental agreements in three stages*

expected benefit of ratification, B, is 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 the variables of our model and influence either positively or negatively the net benefit of ratification of country i for treaty j. The ratification choice is presented as follows:

$$Y_{ij} = \begin{cases} 1, & \text{if } B_{ij}\big(D_i, I_{ij}, T_j\big) > 0 \\ 0, & \text{if } B_{ij}\big(D_i, I_{ij}, T_j\big) \leq 0 \end{cases} \tag{4.3.1}$$

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 income level of a country, 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 by those other nations with which it shares economic or cultural ties, diplomatic connections or are both part of the same international institutions. I is specific to the treaty because the ratification of the agreement by a foreign nation affects the net benefit of ratification solely for agreement j. It does not alter the general net benefit of ratification for all treaties by country i. 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. trade agreements) rather than two agreements dealing with environmental issues (Marrouch & Chaudhuri, 2015). Finally, T encloses the features of the agreement that have an influence on the cost of ratification. T includes whether a treaty is regional or global, the stringency of 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. The variables in B_{ij} and the implementation of this framework are discussed in detail in the next chapter.

Assuming that B_{ij} is continuously differentiable in D, I and T, we are able to draw conclusions on the marginal effect of variables of interest on the willingness to join the environmental agreement, thus answering the questions posed in chapter 2. The marginal effects are obtained conditional on the variables in B_{ij} and assuming that the agreement j has been negotiated. It could be argued that the act of ratification represents the adhesion of a country to the set of ideas and implications of the agreement. If the negotiation position differs strongly from the interests and values of the treaty, ratification is implausible (Bailer & Weiler, 2015). So the act of ratification implicitly bears information on the diplomatic position of a country during negotiation phases. However, given the weakness of this link, no conclusive inference can be made on the impact over the final design of the treaty or on cooperation in environmental issues for which an environmental treaty is not agreed.

Ratification decisions are generally made by the legislative body of the nation 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, but a more realistic representation depicts ratification as the result of conflicting interests within the country. 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. These two forces apply opposing pressure on the decision to participate to the environmental agreement. With an appropriate measure of the strength of environmental and industrial lobbying we are able to infer on their relative impact on ratification decisions. And in a similar fashion, we can provide a better understanding of how the quality of institutions interacts with these dynamics. This framework echoes the recent developments in the economic literature discussed in this chapter, which in recent years have attempted to integrate the public choice approach in the existing game-theoretical literature on participation to environmental agreements (e.g. Marchiori et al. 2017, Habla & Winkler 2013, Köke & Lange 2017 and Lui 2018). 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 large sample of treaties is missing. Our aim is to fill this gap.

4.3.2 Hypotheses on key variables

This section formulates the hypotheses that will be empirically tested in our study. Such hypotheses are derived from theoretical predictions regarding the participation in environmental agreements and the expected impact of country and treaty characteristics on ratification. The hypotheses will be used as an investigation tool to assess our results in the context of the dominant theoretical paradigm.

Interest groups and institutions

The main focus of our research is on the role played by environmental and industrial pressure groups in the ratification process. According to Wangler et al. (2013), lobbying has a significative impact during the negotiation and ratification of environmental agreements. Pressure groups, NGOs and lobbies are able to influence politicians by providing information, raising awareness of electors, providing financial support to government initiatives, funding campaigns or even bribing politicians (Wangler et al., 2013). Inspired by public choice theory, new models are being developed that incorporate the effect of domestic interest groups on treaty participation choices.

According to the model in Haffoudhi (2005), participation in environmental agreements depends on the relative strength of the environmental and industrial lobbies. A similar conclusion is reached by Habla & Winkler (2013) who consider the pressure exerted by a plurality of industrial lobby groups. They find that the decision to participate depends on the aggregate strength of the industrial lobby groups. In Marchiori et al. (2017) stronger industrial lobbies hinder participation in the agreement while environmental lobbies increase the chances of ratifying the agreement whenever lobby groups are allowed to announce contributions before ratification choices and with a policy maker that maximises a political support functions. In Marchiori et al. (2017) the influence of lobbies is assumed to depend both on the level of organisation of the lobby and the preference for "contributions" of the policy maker. The general perspective is that industrial lobbying affects negatively the participation in environmental agreements, leading to the first empirically testable hypothesis:

HYPOTHESIS 1: *The likelihood of ratifying environmental agreements decreases when industrial lobbies are stronger*

According to the same body of literature, the impact of environmental lobbies has the opposite effect. For instance, Hagen et al. (2016) demonstrate that environmental lobbies support the ratification of environmental agreements and lead to larger coalitions. In their model, ratification decisions are based on rival contributions by environmental and industrial lobbies. An equilibrium coalition size and abatement level is derived from a two-stage treaty participation game with heterogeneous countries. Likewise Biancardi & Villani (2010), in a two-stage participation game, show that a higher environmental awareness sustains larger coalitions. The relationship between environmental pressure and ratification has already been explored in a number of empirical studies. Fredriksson & Ujhelyi (2006) and Fredriksson et al. (2007) observe that environmental lobbying has a positive effect on the likelihood of ratifying the Kyoto Protocol (1997). Bernauer et al. (2013b) test the effect of environmental lobbying on a wider sample of environmental treaties, confirming that it increases the likelihood of ratification. In addition, Mohrenberg et al. (2016) find that ratification rates are higher when environmental NGOs have access to the negotiation of environmental agreement. Given the results of theoretical models and the existing empirical evidence in support, we formulate the following empirically testable hypothesis on the role of environmental pressure:

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

The second focus of our research is on the role played by institutions 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 a 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. Roberts et al. (2004) argue that the level of development and the quality of institutions in a country mainly depend on its colonial past. Extraction colonies tend to turn into peripheral countries even after their independence because the political institutions and economic structure of the country were based on the extraction of raw materials to the benefit of 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 (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 of 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 that the effects of both industrial and environmental lobbying are 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*

The set of hypotheses presented in this section are directly related to the research questions advanced in chapter 2: they focus on the effect exerted on ratification by domestic pressure groups and the quality of institutions. It is the first time these effects are studied on a large sample of treaties. The only comparable work is Fredriksson et al. (2007), but that study focuses exclusively on the Kyoto Protocol (1997) and is not intended to produce generalisable results.

International interactions

The ratification choices of different countries are intertwined. Their choices cannot be thought of as being independent from each other. 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, or geopolitical, economic and cultural partners (Bernauer et al. 2010, Perrin & Bernauer 2010, Sauquet 2014, Yamagata et al. 2013, Yamagata et al. 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 benefits of the treaty for non-ratifiers without increasing incentive in participation to other nations (Carraro & Siniscalco, 1998). In the case of minimum participation rule the effect is even adverse, when an additional country — over the minimum participation level — joins the coalition, the other countries have an incentive to leave the coalition (Rubio & Casino, 2005). Milder predictions are generated by models that include issue linkages among treaties, but even in this case, the general assumption is that ratifications do not interact positively unless a grand coalition is formed.

While there is consensus on the inherent interdependence in ratifications, there are opposing arguments regarding the direction of international interactions. The contrasting conclusions lead to ambiguous expectations on the effect of foreign ratifications. 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. As explained in next chapter, we will take into account the influence exerted by the ratifications of big nations and neighbouring countries. Big nations (e.g. US, China, India, Russia) are assumed to have an impact on other countries' behaviour because of the importance of their action for solving environmental issues as well as the diplomatic weight associated with their size. On the other hand, neighbouring countries are likely to share economic bonds, social and cultural backgrounds and generally the same political interests. These links could prompt stronger cooperation on the diplomatic plane (Sauquet, 2014).

Regionality

Last but not least, ratification choices depend on the shape and content of the agreement itself. In fact, the design of the agreement is crucial for its success (Carraro & Siniscalco, 1998). Different empirical attempts have been made to study how treaty design affect participation levels, notably Bernauer et al. (2013b) and von Stein (2008). These attempts are unlikely to capture the entire spectrum of nuances involved in the texts of environmental agreements because it is complicated to evaluate all the features of an agreement, especially for large number of diverse agreements. The ratification costs for a country usually depend on technical clauses, for which full implications are hard to grasp. To make matters worse, information is very limited and the estimated implementation costs are at best imprecise.

Treaty features play a fundamental role in ratification choices, so we employ methodological strategies to account for unobserved treaty characteristics. Our data set comprises more than 250 environmental agreements, with the particularity of distinguishing between global and regional agreements. In theory, cooperation is easier and generally more successful when environmental problems involve a small number of countries. On the contrary, 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. Given that our data allows us to distinguish between global and regional agreements, we will test empirically the following hypothesis:

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

Again, it is the first time regional agreements are studied contextually to global treaties. This is made possible by our special treatment of potential ratifiers. In the next chapter, we will describe in detail the data and the methodological approach employed in the empirical testing of the hypotheses expressed in this chapter.

Chapter 5

Methodology and data

This chapter scrutinises the strategy used to answer the research questions raised at the beginning of the thesis. In the first part we explain in detail the chosen methodological approach and motivate why it is the most suitable to the data and the analysis of ratification. We discuss the modelling choices and the estimation technique. The second part of the chapter is dedicated to the dependent and independent variables of the model. We delineate how the data set on ratification was assembled and emphasise the importance of identifying the potential ratifiers of the treaties. The final section describes the measurement of the independent variables in the model.

5.1 Methodology

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

Do domestic pressure groups influence the ratification of environmental agreements? And how is this relationship affected by the quality of institutions? Are good institutions facilitating international cooperation? In order to answer these questions we must first understand how to "measure" ratification.

The first possibility is to take a sample of treaties and simply count the number of agreements that have been ratified by a given country. Unfortunately, if we want to understand the motivations that push to the ratification of an agreement, 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. Figure 5.1 and 5.2 show that environmental agreements differ greatly in terms of participation and size. This is partly due to the fact that the scale of environmental issues is in itself heterogeneous. Some agreements are small regional agreements setting up local committees, others are important international concordats safeguarding countries from environmental hazards. Each treaty has its own peculiar mix of obligations and economic implications, has a unique scope and deals with environmental subjects having specific individual characteristics. Adding treaties up would mask a plethora of differences in the choice of ratification. For all these reasons, knowing how many agreements a country has ratified does not help us understanding the driving forces behind environmental commitment. We need to distinguish the ratification of each individual treaty instead of lumping them together.

Hence, in measuring ratification, we wish to know *if* a treaty has been ratified by a given country, not the total number of ratifications. It is theoretically possible to cross-sectionally analyse if a treaty has been ratified at one point in time but this approach has some limitations. First, whether a ratification occurred depends on the point in time we choose to assess it. That is to say, ratification could occur later in time and not being taken into consideration. This introduces arbitrariness in the measure of ratification and potentially measurement error. 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 the ratification. We believe that the latter is a crucial aspect in understanding the effects of institutional 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 on the final outcome of ratification, but also on its timing. This is especially true for agreements that succeeded an almost universal ratification. In which case, a strategy based solely on the outcome would

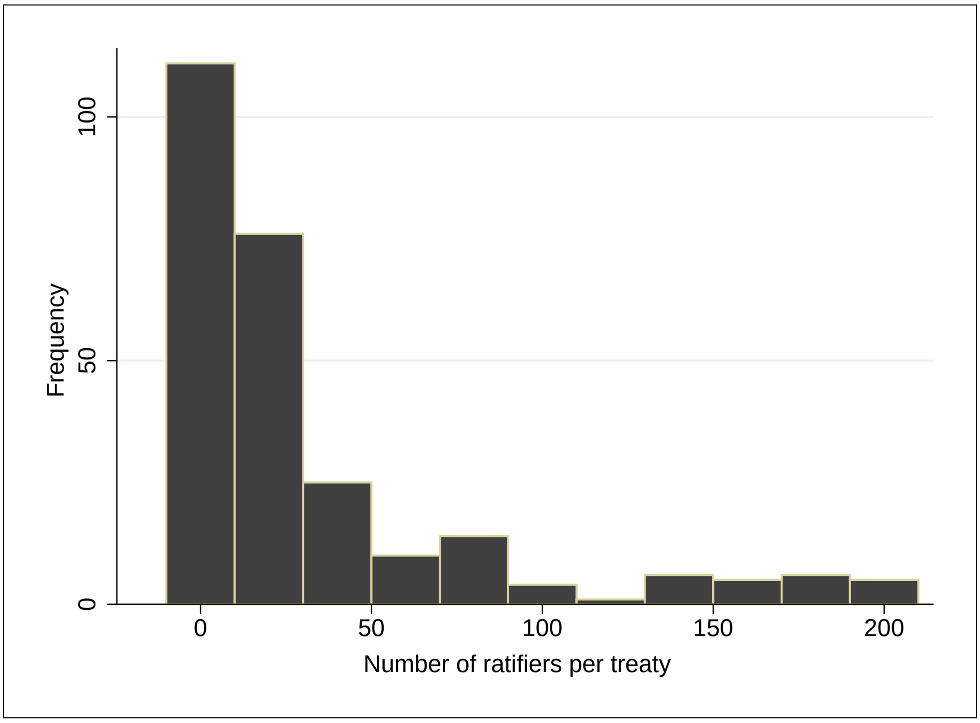

Figure 5.1: *Number of ratifiers*

Notes: Most of the agreements have fewer than 50 members. The low number of ratifiers is not the consequence of countries' reticence to ratify (Fig 5.2), but it reflects that a large part of the cooperation takes place regionally. Hence the relevance of including regional agreements in the analysis.

fail to capture the heterogeneity among countries. The same applies to smaller agreements that are ratified by almost all of the potential ratifiers. To some extent, the more successful a treaty is at securing ratifications, the more important is the timing aspect of ratification. Agreements with high ratification rate represent an important share of our sample (Figure 5.2). For example, the UNFCCC (1992) and the Montreal Protocol (1987) both achieved universal ratification with 197 parties. The ratifications did not occur all at the same time, they are spread over a long period of time. For instance, 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. 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.

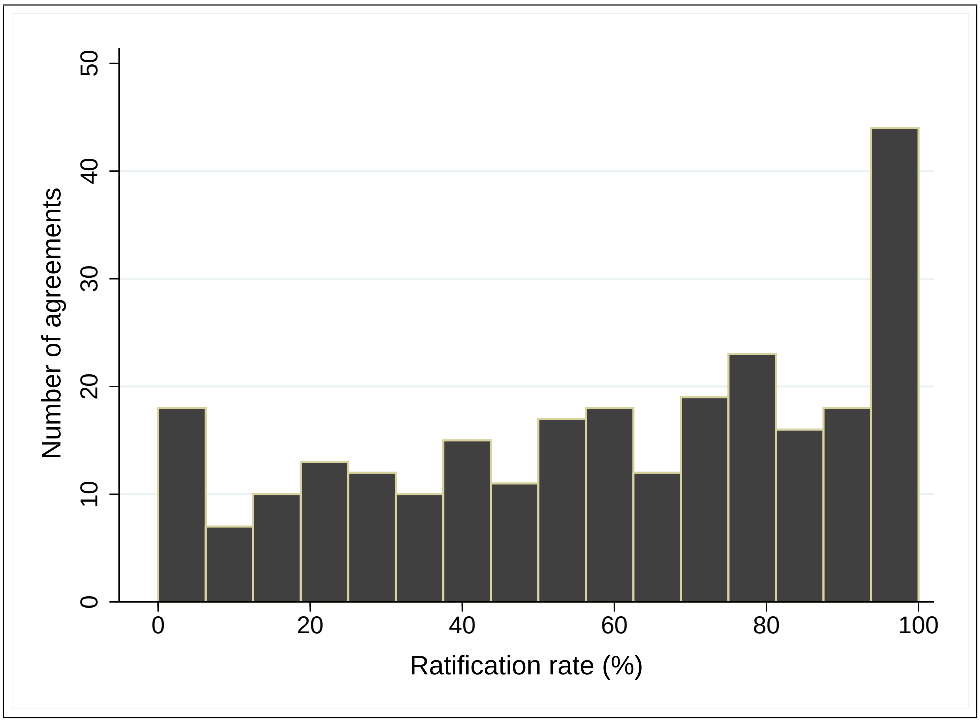

Figure 5.2: *Ratification rate*

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. For more details on the ratification data see section 5.2.2.

In conclusion, to answer the research questions, we are interested in knowing *if* and *when* a treaty is ratified. To this end, we track throughout time the ratification decisions for all treaty-country combinations. In the next section we explain how this strategy is implemented.

5.1.2 Model specification

Our data has the format of survival/duration data which is defined by two sets of information: whether the event (ratification) occurs and the time to the event. Time to ratification starts elapsing from the signature date and ends either with ratification or a missed ratification. The information on ratification is grouped into yearly observations. Despite its continuous nature we reduce the data on ratification into yearly observations in order to match the observation frequency of the explanatory variables. The alternative is 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 monthly or daily time interval would result in a cumbersome number of datapoints. Annual observations are also a natural choice because the independent variables are measured on an annual basis. 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 binary response once every year (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 having an event during the time interval t, given no earlier occurrence:

$$h_i(t) = \Pr\big(y_i(t) = 1 \mid y_i(t-1) = 0\big) \tag{5.1.1}$$

Where y_i and t are respectively the response variable and the event time for every country-treaty combination i. Time is a discrete variable and the hazard is assumed constant over the time interval. Then, our binomial regression has the following form:

$$\text{cloglog}\big[h_i(t)\big] = \log\big(-\log\big(1 - h_i(t)\big)\big) = \alpha(t) + \boldsymbol{X_i(t)\beta} \tag{5.1.2}$$

In equation 5.1.2, $\boldsymbol{\beta}$ is the vector of coefficients for the vector of explanatory variables $\boldsymbol{X_i}$. 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 $\boldsymbol{X_i(t)}$. In practice, time-varying explanatory variables can change throughout time, but we are assuming that they are constant within each time period (i.e. year). $\alpha(t)$ is a function of time called the baseline hazard function. Its form needs to be specified in advance. We choose to use a cubic polynomial (Equation 5.1.3); this approach has been proposed for our type of data by Carter & Signorino (2010). Another viable alternative would be to use splines (Beck et al., 1998), however these have the disadvantage of being less easy to interpret and implement. Carter & Signorino (2010) show that the cubic polynomial and the spline perform similarly. We also opt for the cubic polynomial because it is how temporal dependency in ratification is preferably modelled in the existing empirical literature. 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 affects the estimation time for the model. This assumption will be assessed by testing a non-parametric specification in chapter 6.

$$\alpha(t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 \tag{5.1.3}$$

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) 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. This differs from the odds of hazard ratios produced by a logit model. In fact, the discrete-time hazard rate defined in equation 5.1.1 can also be written in terms of survival time T for the treaty-country i conditional on the covariates $\boldsymbol{X_i}$:

$$h_i(t) = \Pr\big(T_i = t \mid T_i \geq t, \boldsymbol{X_i(t)}\big) \qquad t = 1, 2, ... \tag{5.1.4}$$

applying the properties of conditional probabilities,

$$\Pr\big(T_i = t\big) = h_i(t) \prod_{j=1}^{t-1} \big(1 - h_i(j)\big) \tag{5.1.5}$$

and,

$$\Pr\big(T_i \geq t\big) = \prod_{j=1}^{t} \big(1 - h_i(j)\big) \tag{5.1.6}$$

If t_i is the observed survival time for the treaty-country combination i, then the response variable $y_i = 1$ if $T_i = t_i$ and $y_i = 0$ if $T_i > t_i$. It is possible to derive the likelihood $\mathcal{L}$.

$$\begin{aligned}
\mathcal{L} &= \prod_i \big[\Pr\big(T_i = t\big)\big]^{y_i} \big[\Pr\big(T_i \geq t\big)\big]^{1-y_i} && (5.1.7)\\
&= \prod_i \Big(\frac{h_i(t_i)}{1 - h_i(t_i)}\Big)^{y_i} \prod_{j=1}^{t_i} \big(1 - h_i(j)\big) && (5.1.8)\\
&= \prod_i \prod_{j=1}^{t_i} \Big(\frac{h_i(j)}{1 - h_i(j)}\Big)^{y_i(j)} \big(1 - h_i(t)\big) && (5.1.9)
\end{aligned}$$

As demonstrated by Allison (1982), the likelihood function $\mathcal{L}$ is identical to the one we would obtain for a binary response model that has a probability equal to the hazard function. Note that for the treaty-country combination i, when time j corresponds to the ratification time T_i, then $y_i(j) = 1$. In the other cases $y_i(j) = 0$. The complementary log-log link function allows the discrete model, that has discrete observations, to approximate a survival model with continuous observations grouped in years.

This model assumes that the effect of the hazard ratio is constant throughout time. This assumption is known as the Proportional hazard Assumption. That is to say that, conditional on other covariates, the effect of the variable is the same for all durations. The proportionality assumption could be relaxed by introducing an interaction term between $\boldsymbol{X_i(t)}$ and $\alpha(t)$.

5.1.3 Controlling for unobserved heterogeneity and treaty-country correlation

The model we presented so far is likely to be misleading. We cannot presuppose that the ratification timings and decisions for the same country *vis-à-vis* different agreements are independent from each other. Even after controlling for external effects, there are some specific unobserved factors that are likely to systematically affect the hazard for all events. Failure to account for this would lead to biased coefficients. Similarly, it is reasonable to expect a degree of correlation between the acts of ratifications of an agreement by different countries. Again, the observations for units within the same treaty are not independent and this could lead to biased results. Moreover, for higher durations the risk set will increasingly consist of dyads with low risk of ratification (Figure 5.3). These will participate in the estimation of the baseline hazard and, if we do not control for unobserved heterogeneity, could tend to accentuate the effect of negative factors on duration and understate the effect of positive factors. To sum up, in the case of ratification, unobserved heterogeneity subsists on two different levels: treaty and country. We need to adjust the model accordingly.

For normal responses, unobserved heterogeneity is addressed by including either fixed effects or random effects. However, with survival data fixed effects perfectly predict non-occurrence. In other words, it would exclude all the units for which the event does not occur because their observations are invariantly composed by zeros. The resulting survival estimates would be based solely on the units that experienced the

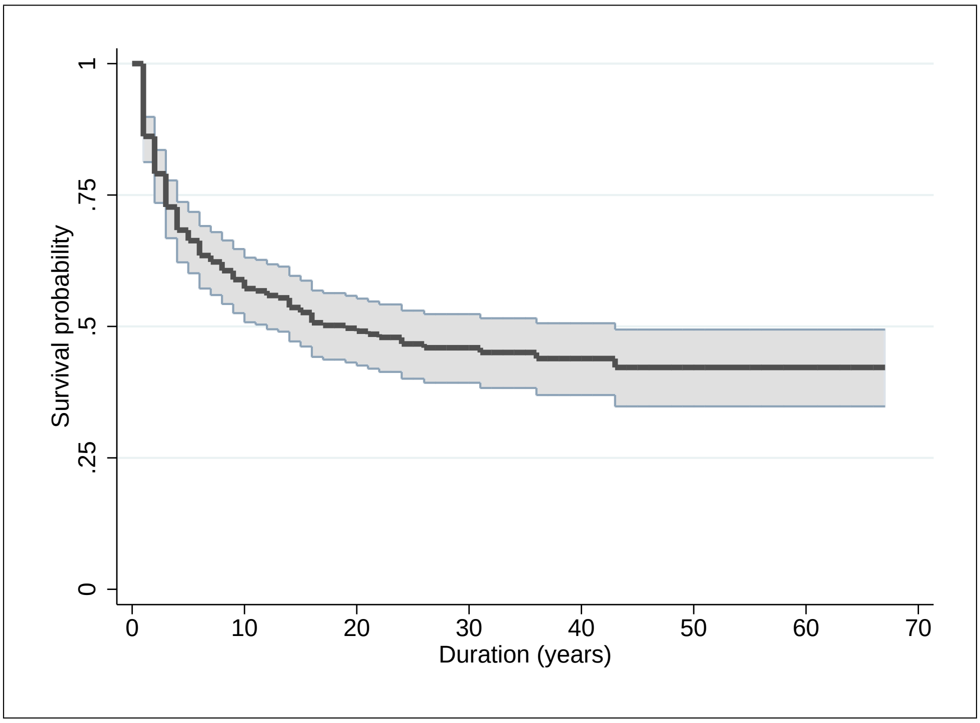

Figure 5.3: *Kaplan-Meier survival estimates*

Notes: The Kaplan-Meier curve is a non-parametric method to derive survival functions. This curve shows that in 20 years a country has approximately 50% of probability of ratification. It also depicts how the likelihood of ratifying a treaty is drastically reduced after the 20 years, with the probability of "surviving" ratification slowly converging to 47% at higher durations, meaning that the remaining countries are very unlikely to ratify at this stage: they have a very low failure rate.

event and consequently biased. As a result, fixed effects are not usable in survival analysis, the only exception being the analysis of repeated events (Allison & Christakis, 2006). In the context of survival analyses, unobserved heterogeneity is modelled with frailty, which correspond to the inclusion of a random effect. Previous studies dealt with this problem by 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 game theoretical literature[1].

What we want to study is how variations in country and treaty characteristics in general influence the chances of ratification. This can be accomplished more parsimoniously by the inclusion of 2 random effects, namely the treaty (u_{j_1}) and country (u_{j_2}) random effects. This means we are assuming the effects to be randomly drawn from a distribution of country and treaty effects defined as in equation 5.1.11. The final model will have the following specification:

$$\text{cloglog}\left[h_{i(j_1 j_2)}(t)\right] = \alpha(t) + \boldsymbol{X_{i(j_1 j_2)}(t)\beta} + u_{j_1} + u_{j_2} \tag{5.1.10}$$

$$\alpha(t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 \tag{5.1.3}$$

$$u_{j_1} \sim \mathcal{N}(0,\, \sigma^2_{u_{j_1}}) \qquad u_{j_2} \sim \mathcal{N}(0,\, \sigma^2_{u_{j_2}}) \tag{5.1.11}$$

We are using the usual multilevel notation for cross-sectional models (Fielding & Goldstein 2006, Goldstein et al. 2002). Units lying at the first level are designated by the subscript i, while variables at the second level by subscript j. The subscript j_1 indicates nesting within the treaty and within j_2 the country. Since both country and treaty effects lie at the same level (not as in a typical hierarchical model), the treaty-country combinations are indicated with ($j_1 j_2$). This notation facilitates the representation of complex types of nesting, particularly in models including more than 3 nesting variables and a complex variance structure. The total variance at level two is $\sigma^2_{u_{j_1}} + \sigma^2_{u_{j_2}}$. It is also possible to include an interaction term between the two random effects. This practice is uncommon and for our data there is no theoretical arguments in favour of this modelling choice.

To be specific, the model we are building is a binary multilevel model for duration data, with cross-classified random effect at level 2. The multilevel structure emerges from the structure of the data which is characterised by the correlation between the observations of same countries and same treaties. This can be thought as process in which the ratification decisions are nested simultaneously within the agreements and the countries. These two levels of nesting (country

[1]See chapter 4.

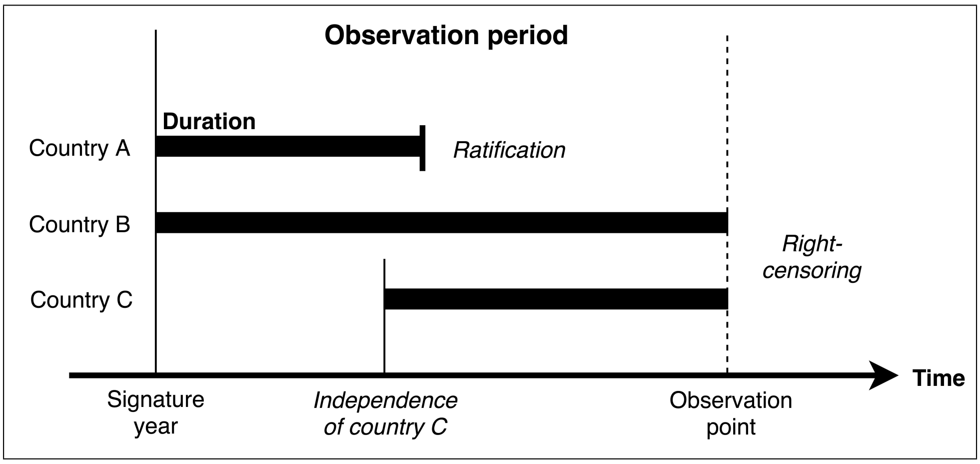

Figure 5.4: *Censoring in ratification data*

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.

and treaty) are not hierarchically organised, as in a typical multilevel model, but they lie on the same level. This sort of model is known as cross-classified multilevel model. If a simple hierarchical model is fitted, and the peculiar structure of the levels is ignored, the resulting estimates would be misleading because, for every cluster, the units on the lower level are considered to be all independent. At the same time, the omission of one of the two random effects leads to severely underestimated standard errors with high probability of engendering type I error in the inference. Hence, it is important to include both country and treaty effects, and to pay attention to the cross-sectional structure of the model.

Estimation through traditional maximum likelihood methods do not perform well because of the complexity of the model and the type of data. Instead, we rely on the Monte Carlo Markow Chain (MCMC) estimation method that we implement in MLwiN. This is a software developed specifically to work with multilevel models. The estimation method will be described in detail in section 5.1.5 and 5.1.6.

5.1.4 Censoring and competing risks

Figure 5.4 illustrates the observation of typical survival spells for a representative environmental agreement. Each survival spell ends either with ratification or a missed ratification [2]. The second case is called right-censoring. Right-censoring typically occurs when the event falls beyond the observation period, as opposed to left-censoring which happens when the event takes place before the observation period. In survival analysis censoring is considered to be non-informative. This means that the timing of the event is independent from censoring reasons.

With our data left-censoring is impossible by definition because the act of signature is always public and the observation period is uninterrupted until 2017. For existing countries, the survival spell starts with the signature of the agreement because it is the moment in which the text of the treaty is agreed and becomes formally open to ratification. If a country does not exist at the moment of signature its survival spell starts from the year it acquires independence. It makes sense to imagine that a country enters in the risk set from the moment the agreement is signed or the country becomes independent, even though the administrative requirements that go with ratification make it almost impossible to ratify the agreement immediately. In essence, left-censoring is not a concern since it is impossible to miss a ratification before the starting of the observation period. This property follows from the fact that a treaty cannot be ratified before it is agreed or before a country becomes independent.

On the other hand, there are two reasons why right-censoring could take place: *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. We will argue that, within our empirical framework, it is possible to 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 reevaluating its participation to 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. For this reason the decision not to ratify cannot strictly be

[2] 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 all countries that become extinct are immediately removed from the risk set.

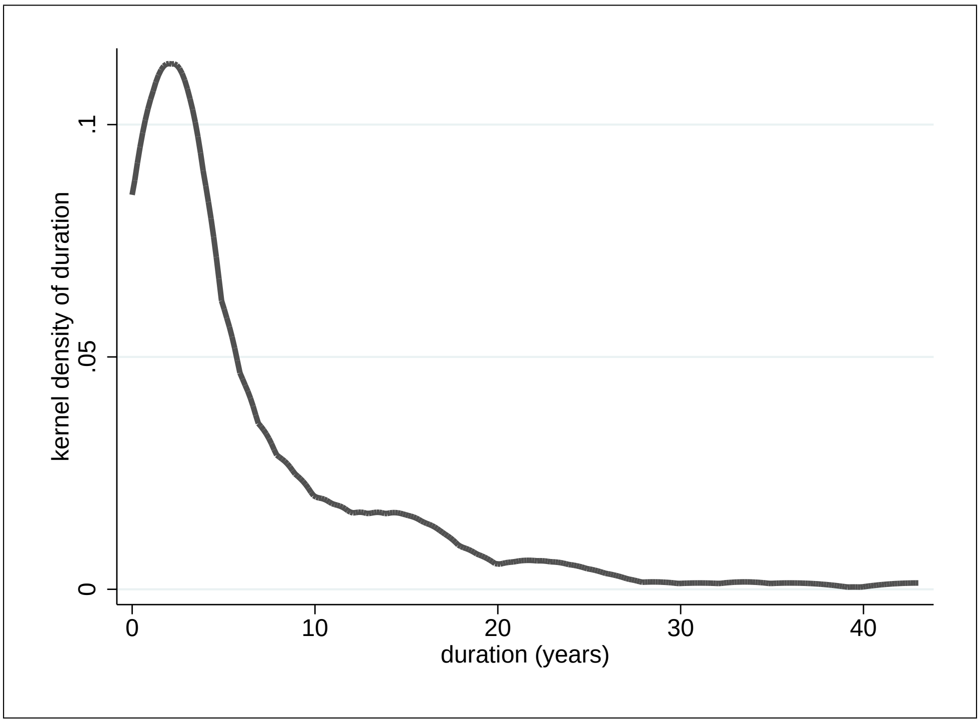

Figure 5.5: *Kernel density estimates of duration for the countries that ratified*

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. The kernel density function gives an approximate representation of the probability distribution of survival times (duration) *for the countries that ratified.*

considered a competing risk. Competing risks are events that prevent the occurrence of the event of interest. It is possible to model competing risks within the framework of survival analysis. The best solution involves right-censoring the survival spell when the competing event takes place. In the case of the decision of not ratifying, not only the occurrence and timing are unknown, but, most importantly, it would be incorrect to right-censor the ratification survival spell because the country could decide to enter in the agreement at any second moment in time. Such a decision does not preclude future ratification but it would certainly delay it.

The second case of right-censoring mainly concerns the most recent agreements in the database since most of ratifications fall in the first 10 years following the signature (Figure 5.5 and 5.3). The event of ratification could occur after the observable time period. This is a classic problem deriving from truncation of the data. Fortunately, if we can assume independent censoring it does not raise difficulties in survival analysis. Independent censoring means that the distribution of the censoring time is independent of survival, conditional on the covariates. If this holds, the censoring timing does not bear any information about our variables of interest; it is non-informative. In the case of ratifications that take place after 2017, truncation time depends on the exogenous year of signature. Hence, the starting year of the life spell is independent from the risk period.

5.1.5 Model estimation

Data transformation

The strategy we described in the previous sections implies expanding the data to cast a discrete survival model in the form of a binomial regression, so that traditional estimation methods can be used (Barber et al., 2000). This is done by taking the survival data and transforming the duration information into a sequence of binary response for each of the years for which the country-treaty is at risk of being ratified. The main disadvantage of this transformation is that the size of the data file greatly expands despite no new information is added. Note that the problem is exacerbated for the dyads having longer observation time. Sometimes, researchers try to mitigate the effect by aggregating time intervals and assuming values are constant over the time interval. However, bundling together observations leads to a loss of information.

In the case of our data, we have 263 agreements and 198 countries observed over a maximum period of 67 years[3]. Thus the potential number of data entries is a rather large 3.5 million combinations. Luckily, not every treaty-country-year combination is in the risk set. In fact, we can exclude all the years after ratification and before the signature of the agreement, as well all the years in which the country did not exist and the combinations for which the country is not a potential ratifier. This reduces the total number of ratification observations to 348377, only one in ten combinations is in the risk set.

[3]We collected data on agreements signed exclusively between 1950 and 2017. The first year of observation for the ratification is 1950 and the last one is 2017

Estimation methods

The new format allows us to fit the model with traditional techniques. Because of the random effect and binary dependent variables, the likelihood of the observed data does not have a closed-form expression. Therefore estimation methods involve approximation. The most popular are quasi-likelihood methods (such as Goldstein & Rasbash 1996 or Breslow & Clayton 1993) and Markov chain Monte Carlo (MCMC) method, although several others have been developed (e.g. adaptive quadrature, simulated maximum likelihood or modified Laplace estimation).

Cross-sectional 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). They work by approximating the discrete multilevel likelihood with a normal multilevel likelihood to allow estimation. These can be adapted for cross-sectional models by including constraints on the model but convergence is harder to reach with larger data sets (Capanu et al., 2013). Softwares such as Stata implement Laplacian approximation for cross-classified random effects. 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 random-effect 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). MCMC is also more convenient in the case of non-continuous data and complex models with cross-classified random-effects because quasi-likelihood becomes increasingly intricate, with numerical integrations over many random effects, while the presence of cross-classified effects does not raise the complexity in estimation through MCMC method (Steele et al., 2004). Furthermore, Beck & Katz (2007) demonstrate that MCMC performs well even when the normality assumptions of the random effects are violated; this result is corroborated by Shor et al. (2007).

We decide to estimate the model using MCMC method because it is a more robust estimation technique. It can be applied to the binary cross-classified model by using the Metropolis-Hasting algorithm as a sampler. This is a simulation method that produces the complete distribution of the parameters instead of providing just point estimates for the mean and the standard error. 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 intrinsic to survival data. Furthermore, with uniform priors and large samples, MCMC yields estimates that are asymptotically equivalent to MLE. This property is derived from the Bernstein-von Mises theorem, which state that with large-enough samples the information contained in the samples 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 that estimation with MCMC is computationally very intensive for data in a binary format and, in addition, MCMC is a Bayesian technique so priors must be stated in advance. The model is estimated 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. The software supports both MCMC and quasi-likelihood estimation.

Estimation of Bayesian models

In Bayesian statistics probabilities are interpreted differently than in the standard frequentist approach. The probability of an event is conceived as the *degree of belief* to which the event is thought to take place. Unlike the frequentist approach, this definition involves a subjective appreciation of the odds linked to the event because it incorporates personal beliefs. This will be reflected in how the parameters of a model are obtained.

In Bayesian modelling, the parameter θ of a model is considered a random variable that cannot be determined exactly, the uncertainty surrounding its value is represented by a probability distribution. The initial view on the shape and densities of this distribution is formed by the researcher and represents the starting point of the analysis. This preliminary statements on the values of the parameter are called *priors* and summarised in the distribution $\pi(\theta)$. The core of Bayesian analysis rests on Bayes' theorem, an equation that offers a system to update the initial beliefs as new data $\boldsymbol{x} = \{x_1, x_2, ..., x_n\}$ is gathered. In fact,

$$\Pr(\theta \mid \boldsymbol{x}) = \frac{\Pr(\theta, \boldsymbol{x})}{\Pr(\boldsymbol{x})} = \frac{\Pr(\boldsymbol{x} \mid \theta)\, \pi(\theta)}{\Pr(\boldsymbol{x})} \tag{5.1.12}$$

Bayes' theorem links the *posterior* distribution $\Pr(\theta \mid \boldsymbol{x})$, i.e. our updated beliefs on which inference is based, with the observations and the prior distribution. With a distributional assumption, $\Pr(\boldsymbol{x} \mid \theta)$ is a function expressing the probability of observing the data $\boldsymbol{x}$ given our prior beliefs on the values of θ. The denominator $\Pr(\boldsymbol{x})$ is the marginal distribution of $\boldsymbol{x}$ and has the property of normalising the posterior, it can also be written also as:

$$\Pr(\boldsymbol{x}) = \int \Pr(\boldsymbol{x} \mid \theta)\pi(\theta)d\theta \tag{5.1.13}$$

The problem with this equation is that, very often, it does not have a closed-form solution. With several parameters, this equation involves many complex integrations. Hence, Bayes' theorem is often written in the following form:

$$\Pr(\theta \mid \boldsymbol{x}) = \frac{L(\theta)\,\pi(\theta)}{\int L(\theta)\pi(\theta)d\theta} \tag{5.1.14}$$

Where the likelihood function $L(\theta)$ is proportional to $\Pr(\boldsymbol{x} \mid \theta)$,

$$L(\theta) \propto \Pr(\boldsymbol{x} \mid \theta) \tag{5.1.15}$$

Notice that the normalising denominator of the equation is an integral and, despite its complexity, does not depend on the parameters since they have been integrated out. Hence, as long as it solves to a finite value, it will not affect the shape of the posterior distribution $\Pr(\theta \mid \boldsymbol{x})$. As a result, the posterior distribution is proportional to the likelihood function and the prior distribution.

$$\Pr(\theta \mid \boldsymbol{x}) \propto L(\theta)\pi(\theta) \tag{5.1.16}$$

The consequence of equation 5.1.16 is that, in theory, the posterior distribution of the parameters can be derived once we obtain the likelihood function and the probability distribution of θ. However, in practice, the integrations lead to posterior distributions that have intractable forms. The sheer complexity of these integrals was a major obstacle to the application of Bayesian methods. Nevertheless, with the increase in computing power new approaches have been developed. In particular, Markow chain Monte Carlo is a simulation technique that bypasses the problem of integration by drawing samples from the posterior distribution which are then used to approximate the value of the parameters of interest. A more detailed explanation is given in the next section.

5.1.6 Markow Chain Monte Carlo (MCMC)

With the exception of simple problems, it is hard to find analytical solution for the posterior distribution. Hence, instead of calculating the posterior distribution, MCMC avoids the problems by simulating draws from it. MCMC extracts samples from a target distribution that are used for inferences on the parameters of the model. The samples are taken from the conditional posterior distributions because it is generally hard to simulate from the posterior distribution itself. It has been demonstrated that sampling from the conditional posterior distributions in succession is comparable to sampling directly from the joint posterior distribution (Chib & Greenberg, 1996). The method works by drawing a large number of consecutive samples; each of the samples should depend exclusively on the previous one. This is formalised by using the mathematical notion of Markow chains. Markow chains are a sequence of random variables θ^1,θ^2,..., θ^n that exclusively depend on the value of the previous one. That is to say:

$$\Pr(\theta^{n+1} \mid \theta^1, ..., \theta^n) = \Pr(\theta^{n+1} \mid \theta^n) \tag{5.1.17}$$

The future value of the process exclusively depends on the present value. Any past information affects the future value only through the present one. These repeated samples are driven by an algorithm that expresses the way the sample draws move through the distribution. In the case of our research we use the Metropolis-Hastings algorithm because the conditional posterior distribution of our model is not workable with Gibbs sampler.

To sum up, the aim of MCMC is to draw a series of independent samples that are used to summarise the (joint) posterior distribution of the parameters. The mean, standard deviation, density plots and quantiles of the posterior distribution are all derived from these random samples. The most important property of MCMC is that the Markow Chain will converge to the target distribution independently from its starting point or the complexity of the model. The longer the simulation is carried out, the more accurate the approximation is. The accuracy can be elevated to any degree of precision if the simulation is long enough. Of course, the issue here is the practical obstacle of time, because complex simulations are extremely time consuming.

Metropolis-Hastings algorithm and convergence

The algorithm was first proposed by Metropolis & Ulam (1949) and Metropolis et al. (1953). Their work was then generalised by Hastings

(1970), hence the name of Metropolis-Hastings. The algorithm allows to draw independent samples from the joint distribution of multiple variables. Gibbs sampler (Geman & Geman, 1984) can be reconducted as a special case of the Metropolis-Hastings algorithm.

In MCMC, the generation of new values for a parameter is done on the basis of a *proposal distribution* that is used to iteratively obtain values that are either rejected or accepted as a replacement of the current estimate. The proposal distribution could have any shape, but it needs to be easy to sample from. We use a random walk proposal distribution, which corresponds to a normal distribution centred on the current parameter θ. This also has the advantage of being symmetrical, meaning that at time t,

$$\Pr\big(\theta(t) = a \mid \theta(t-1) = b\big) = \Pr\big(\theta(t) = b \mid \theta(t-1) = a\big) \tag{5.1.18}$$

Metropolis-Hastings then involves the following steps:

1. Draw a new θ^* from the proposal distribution $\theta(t) \sim \mathcal{N}(\theta(t-1), \sigma_p^2)$, where σ_p^2 is the variance of the proposal distribution

2. Calculate the posterior ratio r_t. For a simple variance component model, with residual variance σ_e^2

$$r_t = \frac{\Pr\big(\theta^*, \sigma_e^2(t-1) \mid y\big)}{\Pr\big(\theta(t-1), \sigma_e^2(t-1) \mid y\big)} \tag{5.1.19}$$

3. Define the acceptance probability $a_t = min(1, r_t)$. Then, the proposed value $\theta(t) = \theta^*$ is accepted with probability a_t otherwise $\theta(t) = \theta(t-1)$

These steps are repeated until the desired number of samples is reached. The role of the algorithm is to generate new values that are accepted or refused; in the latter case the Markow chain remains on the same value. The algorithm will move until reaching convergence with the target distribution. The main problem with the algorithm is that the proposal distribution tends to create samples that are auto-correlated because the samples are a realisation of a Markow chain. As a consequence, it is often necessary to run a large number of iterations before reaching convergence. Since it is impossible to run an infinite number of iterations, a special attention should be devoted to checking the convergence of the Markow Chain. In the result chapter we assess the convergence of the posterior distribution by *i*) analysing the distribution of the chain values and traces. *ii*) calculating Raftery-Lewis and

Brookes-Draper statistic for the convergence rate, *iii*) calculating the effective sample size (ESS), *iv*) assessing autocorrelation through autocorrelation and partial autocorrelation functions, and *v*) Estimation of the model from different starting points to rule out pseudo-convergence.

In order to increase 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. The applications to our data seem to corroborate their thesis: the number of independent samples we obtain highly increases and we notice a general improvement in the mixing of the Markow chains. Orthogonal reparametrisation involves a substitution of the parameters of the model 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. For more details on the algorithm employed for this form of parametrisation refer to Browne (2017).

In addition to the issue of convergence, the part of the chain obtained before convergence needs to be appropriately discarded, otherwise the inferences could be biased. The initial simulation period that we discard is called burn-in. The final inference of the value of the parameters is be made on the summary distributions of the remaining portion of the Markow chain. The median, mode or mean of the chain is used as the parameter estimate for the model. With diffuse priors this estimation method mimics likelihood maximisation (Rabe-Hesketh et al., 2002). MCMC estimation is time-consuming, however for random effects models the estimates obtained with this method are more accurate than with the methods mentioned in section 5.1.5.

Priors

We have seen that in Bayesian statistics the estimation of the parameters starts from an initial value and prior distribution that is then updated, by following precise rules, as new evidence is gathered. The posterior value and distribution obtained from this process form the starting point for a new sequential update of the beliefs on the parameter values. This process is repeated until the end of the analysis. Now that we understand how the mechanism works, we need to discuss the starting point of the estimation, that is to say our priors.

The priors for every parameter of the model have to be stated in advance because they constitute the starting point of the analysis. According to their nature, the priors can be *uninformative* or *informative*. Uninformative priors are priors that are set in such a way as to have very small effect on the posterior distribution of the parameter. These are also called "flat" or "diffuse" priors. They are an attempt to minimise the impact of the prior specification, thus they are often seen as more objective. On the other hand, informative priors are priors that dominate the likelihood and have a strong effect on the posterior distribution. Nonetheless, as the number of draws tends to infinity, the impact of any type of prior on the posterior distribution shrinks to zero. The impact of the prior is reduced for larger data and longer simulations because with sufficiently long simulations MCMC estimates are guaranteed to converge on the true posterior distribution from any starting distribution.

For the purpose of our analysis we use "diffuse" priors. For the parameters of the model (α and β in equations 5.1.10 and 5.1.3) we use the following priors:

$$\Pr(\boldsymbol{\alpha}) \propto 1 \qquad \Pr(\boldsymbol{\beta}) \propto 1 \tag{5.1.20}$$

Where $\boldsymbol{\alpha} = \{\alpha_0, \alpha_1, \alpha_2, \alpha_3\}$ are the coefficients of the baseline hazard and $\boldsymbol{\beta} = \{\beta_1, ..., \beta_n\}$ the coefficients of the n independent variables of the model. They are improper uniform priors. These priors are called improper because they do not integrate to 1, meaning that they are not probability distributions. However, this is not important to us because we just need the posterior distribution to be a proper probability distribution integrating to 1. This is guaranteed by the finite normalising constant[4]. The priors roughly correspond to Normal distributions with extremely large variance, giving the shape of a flat line. On the other hand, the scalar variances have the following priors;

$$\Pr(\sigma_{u^T}) \propto \mathbf{\Gamma^{-1}}(\varepsilon, \varepsilon) \qquad \Pr(\sigma_{u^C}) \propto \mathbf{\Gamma^{-1}}(\varepsilon, \varepsilon) \qquad \varepsilon = 10^{-3} \tag{5.1.21}$$

This is a proper prior — it integrates to 1 — and corresponds to a uniform prior for the logarithm of the variance. In addition to that, we use the estimates obtained from quasi-likelihood estimation as starting value for the parameters of the model. The values are obtained from a model in which we ignore the cross-sectional nature at the country and treaty levels (i.e. assuming a hierarchical model with countries nested within treaties) and estimating the value of the parameters through first-order Marginal Quasi-Likelihood (MQL) procedure. This should accelerate the convergence of the Markow chains by giving a good initial value.

[4]The denominator in equation 5.1.14

Estimation summary

The estimation of the parameters of the model starts with the transformation of the duration data into a binary format. The data is then used to fit a simplified hierarchical model with quasi-likelihood method. The results we obtain are taken as starting point for the MCMC analysis together with the priors earlier defined. With large samples, diffuse priors also yield estimates that are asymptotically equivalent to MLE. The simulation is run for as many iterations as possible to guarantee the convergence of the series and reliable inference from the posterior distribution. In general we run no less than 500000 iterations. The convergence to the target distribution is evaluated through a number of tests and measures. To accelerate the convergence rate and improve the efficiency of MCMC estimation we use orthogonal reparametrisation. We recapitulate here the priors and the specification of the model using standard multilevel notation (Fielding & Goldstein 2006, Goldstein et al. 2002).

$$\text{cloglog}\left[h_{i(j_1 j_2)}(t)\right] = \alpha(t) + \boldsymbol{X_{i(j_1 j_2)}(t)\beta} + u_{j_1} + u_{j_2} \tag{5.1.10}$$

$$\alpha(t) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 \tag{5.1.3}$$

$$u_{j_1} \sim \mathcal{N}(0,\, \sigma^2_{u_{j_1}}) \qquad u_{j_2} \sim \mathcal{N}(0,\, \sigma^2_{u_{j_2}}) \tag{5.1.11}$$

$$\Pr(\boldsymbol{\alpha}) \propto 1 \qquad \Pr(\boldsymbol{\beta}) \propto 1 \tag{5.1.20}$$

$$\Pr(\sigma_{u_{j_1}}) \propto \boldsymbol{\Gamma^{-1}}(\varepsilon, \varepsilon) \qquad \Pr(\sigma_{u_{j_2}}) \propto \boldsymbol{\Gamma^{-1}}(\varepsilon, \varepsilon) \qquad \varepsilon = 10^{-3} \tag{5.1.21}$$

To sum up, we have modelled the hazard of ratifying a typical environmental treaty by a representative country. The presented model is intentionally "general". It is useful not only to derive overall conclusions on the role of institutions and pressure group, but also to understand the forces that push and hinder the ratification of environmental treaties. Despite this, the model can be fine-tuned to produce information for specific countries or specific treaties. In the second part of chapter 6 we show some practical applications of the model by generating estimates on the probability of ratification for given treaties and countries.

In the next two sections we describe the data set assembled to answer the research question. Section 5.2 explains what treaties are included in the analysis and how ratifications are tracked for all countries.

While in the subsequent section we discuss the variables in the vector $\boldsymbol{X}$ of equation 5.1.10.

5.2 Ratification as dependent variable

5.2.1 Ratification data: format and collection

Format of the data

The dependent variable is a dichotomous variable representing the ratification of an environmental agreement, by a country, in a specific year. In other words, for every combination of country-treaty-year, we observe a binary response that takes the value of 1 if the country ratified the treaty in year t, or 0 if it did not. In case of ratification, the country-treaty dyad is removed from the risk set. This is necessary to avoid biased results. In fact, a series of 1s would indicate that the country is repeatedly ratifying the treaty. On the other hand, if the treaty is not ratified by the end of the observation period, the series for the treaty-country dyad is exclusively composed by zeros.

For every country-treaty dyad the survival spell starts from the year of signature of the treaty, unless the country didn't exist at the time of negotiations, in which case we use the country's independence year as a starting point (see figure 5.6). To be more precise, the signature year refers to the year in which the agreement is opened for signature (and consequentially ratification), rather than the specific year in which signature by country i takes place. The reason for this is that a country could ratify a treaty without signing it — so called accession. In addition to that, agreements normally receive signatures on behalf of the negotiating countries soon after the text of the treaty is agreed. Thus, signatures tend to be grouped together. It is rare to have treaties signed after the first year of the agreement's life and the treaties are often open for signature only for a limited time period (Hugh-Jones et al., 2018).

Sample of treaties and source of the data

We have 2 main sources for the date and status of ratification of treaties: The ENTRI (CIESIN, 2013) and the IEA (Mitchell, 2017) Data-

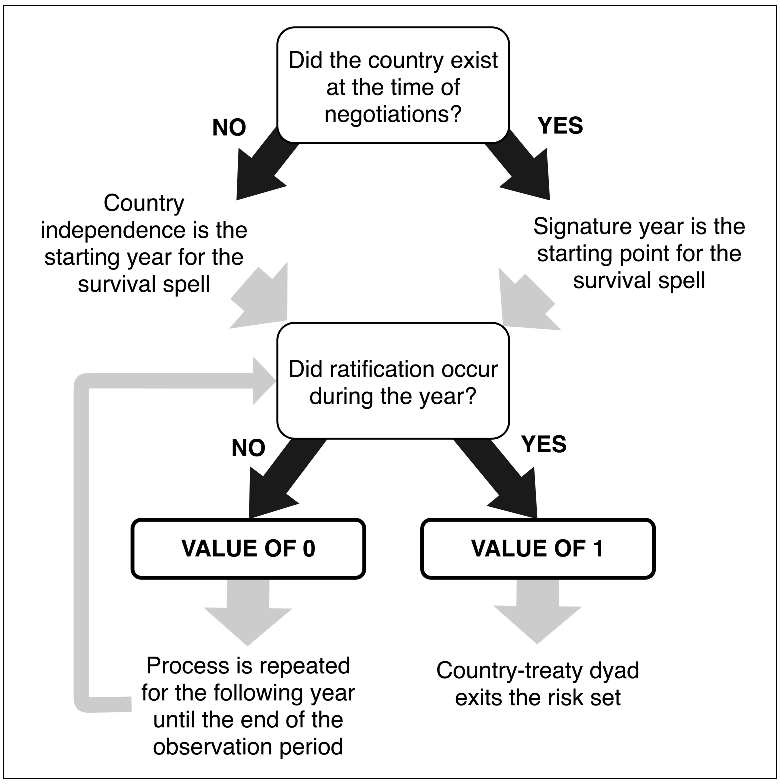

Figure 5.6: *Transforming ratification data into a binary format*

bases. The Environmental Treaties and Resource Indicators (ENTRI) database has been compiled by the International Union for the Conservation of Nature and Natural Resources. It includes environmental agreements signed from 1940 to 2012. In total, 200 countries and more than 600 multilateral environmental agreements are covered by the database. We used it mainly to cross-check the information contained in the International Environmental Agreements (IEA) Database which contains over 1250 multilateral agreements signed between 1850 and 2017 by over 200 countries. The definition they adopt for "environmental" is broader, hence it includes a larger number of agreements than the ENTRI database. For example, it also contains data about energy agreements or nuclear non-proliferation treaties. We focus exclusively on binding agreements that relate to any of the following areas of interest: *i*) protection of the environment in general, *ii*) species protection, *iii*) pollution (air, land and water), *iv*) habitat and ecosystem preservation. As a further restriction, only agreements and protocols to the agreements are taken into consideration, while amendments are ignored. The reason behind this choice is that most of the time amendments imply minor changes in the text of the agreement; they only partially modify the obligations of the parties, without creating new areas of regulation. Furthermore, the amendments tend to be adopted internally to the agreements and sometimes do not require a formal act of ratification.

Finally, we intentionally exclude all bilateral treaties from the analysis. Bilateral treaties tend to be negotiated differently than multilateral agreements. Bilateral agreements are often formed through the medium of embassies and diplomatic visits; the ratification of these agreements can often be carried out by plenipotentiary and representatives of the government, while multilateral agreements generally require the approval by the country's parliament. The underlying determinants of ratification for these agreements would be different. In addition to that, the ratification rate of bilateral agreements is extremely high. Thus, the question of interest for this type of agreements is not so much whether or not the agreement is ratified, but whether or not the two nations decide to negotiate a treaty on the environmental issue. The second question requires a different set of information and goes beyond the interest of this study, which focuses on ratification, not on negotiation. Since small multilateral agreements could share some of the characteristics of bilateral agreements, we limit our analysis to the agreements that have at least 5 potential ratifiers[5]. With these restrictions the number of agreements that meet our criteria is drastically reduced: in total the final data set contains 263 agreements (listed in Appendix B). This remains the largest data set applied to the question of ratification.

5.2.2 Treaties, countries and the problem of potential ratifiers

Potential ratifiers

Mitchell (2017) and CIESIN (2013) report a list of treaties together with the signature and ratification dates of the countries that signed and/or ratified that agreement. However, to correctly estimate our model we need to know all the countries that are in the *risk set*. In other words, for every treaty we need to take into account the countries that ratified and those for which the treaty was open but did not ratify.

[5]Potential ratifiers are the potential members of the treaty, independently of whether the country actually ratified the agreement. A complete definition is provided in the next section.

We can distinguish between two categories of multilateral agreements: global and regional. The former encompasses the agreements that, in principle, concern every nation on earth; as such, every country is a candidate ratifier for this type of agreements. All the remaining multilateral agreements are regional, in the sense that they only regard a subset of nations. We can include regional agreements in our data set as long as we know exactly the nations that are able to ratify or bear an interest in the treaty. We call these countries the potential ratifiers of a treaty.

Unfortunately, the concept of potential ratifier has been dangerously neglected in the ratification literature. The current empirical literature assumes that every country in the world is a potential ratifier of the agreement. While the assumption holds for global agreement, this leads to an overestimation of the survival probability if applied to other types of treaties. In all of the previous studies no one has addressed this limitation. The result is that, in many cases, the inference is completely unreliable because of the erroneous identification of the agreements on which the analysis is based. This is the first time that potential ratifiers of every treaty are clearly identified, thus tackling a major source of bias and allowing us to expand the analysis to regional agreements. In the remaining part of this section we explain the concrete methods used to identify the potential ratifiers of a treaty.

Identifying the potential ratifiers

The potential members of a regional agreement are identifiable if they are stated in the text of the treaty. This is very often the case for regional agreements. In some other cases the ratification is open exclusively to members of a previous convention. Typical examples for this are the protocols to an existing framework convention: even if not explicitly stated, *de facto* the ratifier of the protocol needs to be a member of the convention as well or at least a potential ratifier of the convention. Another set of regional treaties is negotiated by pre-established groups of countries. For example, the Long-Range Transboundary Air Pollution agreements (LRTAP) are negotiated under the banner of the UN Economic Commission for Europe (UNECE), hence all UNECE members are considered in the risk set. Other examples of organisations that develop internal environmental treaties are the European Union, African Union, ASEAN, Commonwealth of Independent States (CIS), or the African, Caribbean and Pacific group of States (ACP).

The *raison d'être* of environmental agreements is to address an environmental issue. Because of this correspondence between the environmental problem and the scope of the agreement, it is often possible

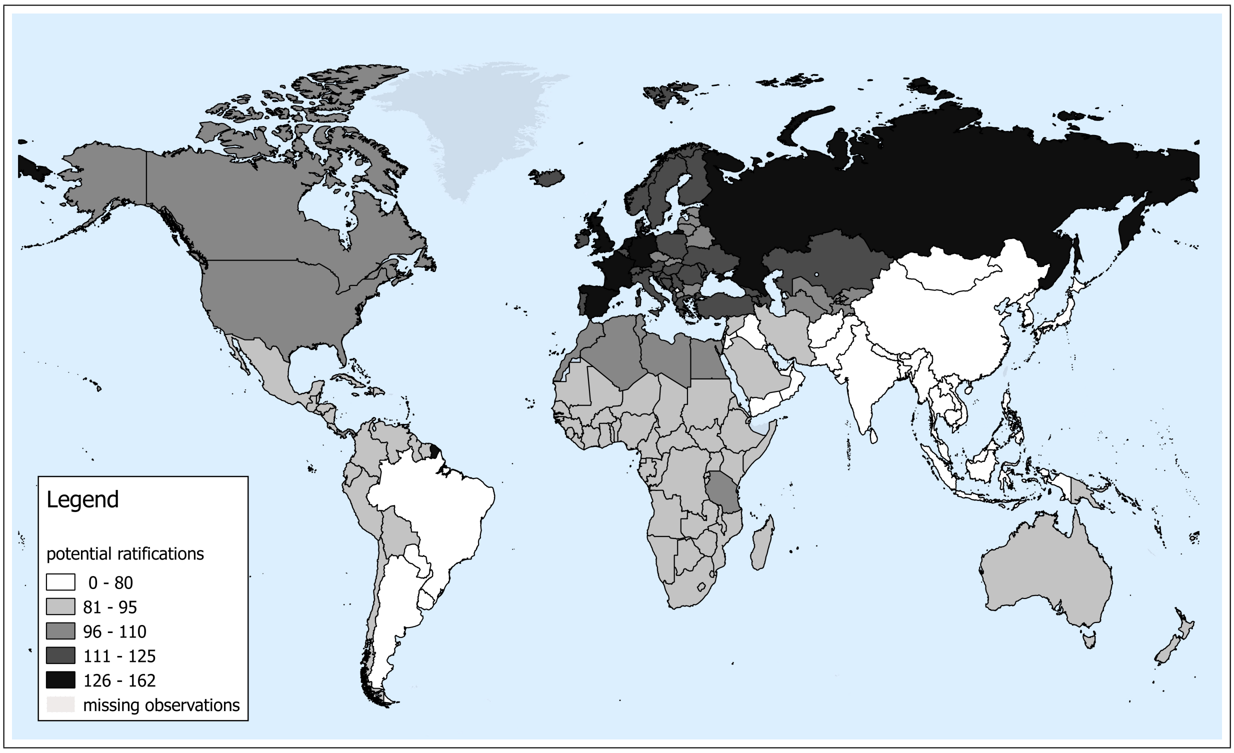

Figure 5.7: *Potential ratifications*

Notes: This map shows the number of agreements in the data set that countries can potentially ratify.

to geographically localise the members concerned by the agreement. For a treaty regarding the pollution of the Danube, the nations that are crossed by the Danube are naturally potential ratifiers of the treaty. The Alpine convention regards the countries in the region of the Alps: Indonesia and Peru are clearly not potential ratifiers. This principle can be extended to a large number of regional agreements; if the agreement tackles a local natural resource, which can be demarcated geographically, then the identification of its potential members follows easily. When the potential members of an agreement cannot be identified unequivocally by the text of the treaty or one of the above-mentioned criteria, the treaty is excluded from the data set. In total we excluded less than 10 agreements.

The potential ratifiers of global agreements

Global agreements are open to every nation in the world. Typically this category of agreements addresses universal problems such as climate change, depletion of the ozone layer, desertification or sea pollution. They can also concern more general aspects related to environmental issues such as the liability for environmental damages, disposal of wastes, protection of species, or general laws on plants, prevention of environmental disasters, or compensation and cooperation on environmental matters. In the case of global environmental agreements any existing country is a potential member. This is less simple to implement than it first appears. First, we need to define the ratifiers at any point in time. We decided to restrict our sample to sovereign nations. Hence, the analysis excludes all the states that are not sufficiently recognised internationally (e.g. Northern Cyprus, South Ossetia, Artsakh or Transnistria) or international entities with no control over their foreign policy[6] or which fail to qualify as fully sovereign nation[7]. We also ignore the ratification of international organisations — both NGOs and inter-governmental organisations — and supranational organisations (e.g. European Union). Even if one of these entities ratifies a treaty we do not take it into account. Moreover, we drop the following 4 countries because of the lack of consistent data: South Moluccas, South Vietnam, South Yemen and East Germany.

As a second complication, the treaties in the sample span from 1950 to 2017. During this period many countries appeared, merged or disappeared from the world map. We must duly account for this by taking into consideration a nation's date of creation/independence and disappearance, if applicable. Information on the independence of nations is collected from World Factbook (CIA, 2017). The countries are in the risk set only if they exist at the time of the signature of the agreement (see figure 5.6) and leave the risk set if the country is extinct. For example, for a treaty signed in 1990: Czechoslovakia would be in the risk set from 1990 to 1993 while Slovakia and Czech Republic from 1994 to 2017. Of course, Czechoslovakia, Czech Republic and Slovakia could leave the risk set earlier if they ratify. In Appendix A we report the full list of countries included in the sample together with information on their creation and extinction (if they occur between 1950 and 2017). In total there are 198 countries and 263 environmental

[6]For example, this is the case of colonial territories until their independence or dependencies such as Puerto Rico that have limited control over their foreign policy.

[7]For example, the Sovereign Military Order of Malta which is widely recognised, possess extraterritorial land in Rome, and even citizenship. However, it is not considered a sovereign nation.

agreements in the sample, of which 190 are regional and 73 global. For each of these treaties we identified the potential ratifiers out of the 198 countries and the years during which those countries are at risk of ratifying. A complete list of the agreements in the data set is available in Appendix B.

5.3 Description of the independent variables

5.3.1 Main variables

Environmental lobbying We adopt a loose definition of environmental lobbying, encompassing all actions aimed at influencing the outcome of ratification decisions in favour of participation. In democracies, the lobbying action can be channelled both through political representation and through the pressure exerted by civil society. The probability of ratification is expected to increase with environmental lobbying. Lobbying, as a variable, is very difficult to measure. It would be interesting to quantify it with the economic resources of environmental groups. Unfortunately this sort of data is unavailable and it would not entirely reflect the complexity of the lobbying effort. Hence, in the literature, environmental lobbying is proxied by the number of environmental non-governmental organisations (ENGOs). This obviously cannot capture the qualitative aspect of lobbying. However, it is often regarded as the best available measure. In general, it is reasonable to assume that the strength of environmental lobbying increases with the number of ENGOs. We use the number of ENGOs memberships by country to the International Union for the Conservation of Nature (IUCN) in 2017. IUCN is one of the oldest and largest environmental organisations; it has around 1300 members, including governments, universities and NGOs. In a second part of our empirical analysis we perform sensibility checks by using the following alternative proxies for environmental lobbying: *i*) the percentage of territory that is designated as protected area ($ProtectedArea$), which we assume correlates with the influence of environmental lobbies, and *ii*) the "environmental concern" of the population ($EnvConcern$). The "environmental concern" is the percentage of population that reports being concerned about climate change in a survey conducted in 119 countries by Tien et al. (2015). The main argument being that the environmental pressure should increase with stronger environmental concerns, both through civil society organisations and political channels. The relationship could be affected by cultural and political factors, but — in general — a stronger environmental concern should result in more environmental pressure. Besides cultural factors, environmental concerns are also likely to be influenced by the level of income (Environmental Kuznet Curve), so we will have to control for this in our model.

Industrial lobbying We anticipate a negative relationship between industrial lobbying and ratification. The term "industrial" is used to loosely indicate a group of economic and political agents that oppose environmental agreements and the introduction of tighter environmental regulations. This group includes highly-polluting companies, fossil fuel producers, energy-intensive activities, but also entities from other sectors that share similar economic interests regarding environmental regulations. Again, the lobbying activity of industrial interest groups is opaque and hard to identify. Recently some data has been compiled for a small number of countries on lobbying expenses. However the data is seriously incomplete and only represents the tip of the iceberg. We use the sum of fossil fuels rent as a percentage of GDP ($ResourceRent$) to approximate the influence of industrial groups. The data is calculated by the World Bank, and is termed "Total natural resources rent (%GDP)" in the WDI data set (World Bank, 2017a). The rents are calculated as the difference between the average production cost and the commodity price. Hence, the variable captures the extent of the monopolistic power enjoyed by the fossil industry; we assume this correlates with their lobbying potential. Then, in a second part of the analysis, other measures are experimented, these include: *i*) the share of GDP value added from manufacturing, mining and utilities at current prices ($ShareIndustry$), data from UNSD (2017), *ii*) a dummy variable ($IMFresourcerich$) for countries classified as resource-rich by the IMF (IMF, 2012), *iii*) $FossilExports$; the share of fossil fuels, ores and metals export over the total value of the merchandise export (World Bank, 2017a) and *iv*) $EnergyUse$, the energy use of the country in per capita terms (IEA, 2017). Higher exports of fossil resources and energy-intensive production are assumed to correlate with industrial lobbying potential because of the existing link between energy-intensive processes and several forms of pollution. Some of these proxies could correlate with economic factors such as the level of income and development or the quality of the environment. Hence, it is important to control for these factors in our equation.

Quality of Institutions The quality of institutions is an eclectic notion. We focus on the concepts of transparency, corruption and efficiency of bureaucracy, which are used as a proxy for the general institutional quality. These concepts tend to be strongly correlated and are directly linked to the success of many forms of interest lobbying. Several indices have been developed to measure the quality of institutions. The most popular being: World Governance Indicators (World Bank, 2017b), Economic Freedom Index and its component by the Fraser Institute (2017), Corruption Perception Index (Transparency International, 2017), "Institutions" pillar of Global Competitiviness Index (World Economic Forum, 2017) and the scores from the International Country Risk Guide (Political Risk Service, 2011). We mainly use the Control of Corruption indicator ($Institutions$) from the World Governance Indicators (World Bank, 2017b), expressed in units of a standard normal distribution. This has the advantage of being directly related to our definition of quality of institutions, calculated for a large base of countries and a sufficiently long period of time. Moreover, to study how lobbying varies with the quality of institutions, we add two interaction terms: between *institutions* and *environmental lobbying* and between *institutions* and *industrial lobbying*. We expect a negative coefficient for both interactions. That is to say, we expect lobbying to be more effective when the quality of institutions is poorer. The results are then confronted with those obtained by substituting the Economic Freedom Index ($Institutions3$) with Fraser Institute Fraser Institute (2017) and Government effectiveness indicator ($Institutions2$) from the World Governance Indicators (World Bank, 2017b). For all indicators, a higher score indicates better institutions.

We follow the practice of controlling for the quality of democracy since this could affect the extent to which environmental preferences are represented within the government — often expressed through vote and other civil rights. The effectiveness of environmental and industrial lobbying could depend on the environmental stance of government. However, this interaction is not modelled because it is not deemed to be a major factor in the effectiveness of lobbying action. The existing empirical research on the subject did not unveil a systematic impact on ratification (Schulze, 2014). Future research could further explore the link between government's identity and ratification probabilities.

Table 5.1: *Definitions and sources*

Variables	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. We assume a constant value over the entire time period because no panel data is available. We perform sensibility checks with other time-varying proxies for environmental lobbying.
$ResourceRent$	Sum of fossil fuels rent in percentage of GDP. “Total natural resources rent (%GDP)” in 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, 2017).
$FreedomHouseCL$	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).
$ThreatenedSpecies$	Red List Index. The index indicates the conservation status of species groups in a territory. A higher risk of extinction is associated with lower scores. Data from IUCN website (IUCN, 2017).
$logForest$	Natural logarithm of the forest area, expressed in thousands of squared kilometres. Own calculations from data on the total land surface (FAO, 2017) and the percentage of land covered by forest (World Bank, 2017a).
$RatRegion$	Share of countries in the same region 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.

Definitions and sources (continued)

Variables	Definitions and sources
$RatIndia$	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.
$Regional$	Dummy variable that takes 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).
$FrameworkAgreement$	Dummy variable that takes the value of 1 if the agreement is a framework agreement (typically with non-binding obligations) according to classification from Mitchell (2017).
t	Duration: number of years the treaty-country combination has spent in the risk set.
$EnergyUse$	Energy use per capita, in kg of oil equivalent. Data from the International Energy Agency (IEA, 2017).
$ShareIndustry$	Share of GDP value added from manufacturing, mining and utilities at current prices. National accounts data (UNSD, 2017).
$IMFresourcerich$	Dummy variable that takes the value of 1 if the country is on the IMF list of resource rich countries (IMF, 2012). The IMF identifies resource-rich countries mainly on the basis of their reliance on the export of natural resources.
$FossilExports$	Export of fossil fuels, ores and metals over the total value of the merchandise export. Data from WDI (World Bank, 2017a).
$EnvConcern$	Percentage of population that reports being concerned about climate change. Data from Tien et al. (2015) based on a survey conducted in 2007-2008 that covers 119 countries, with 500 to 8000 respondents per country.
$ProtectedArea$	Percentage of terrestrial territory that is designated as protected area. The data is from UNEP (2017). For missing values the variable is assumed constant.

Definitions and sources (continued)

Variables	Definitions and sources
$Institutions2$	Government effectiveness indicator from the World Governance Indicators (World Bank, 2017b). Expressed in units of a standard normal distribution.
$Institutions3$	Economic Freedom Index by Fraser Institute (2017). Score ranges from 0 to 10. Data is annual from 2000, but it is only available on a 5 years basis between 1970 and 2000. The missing years are filled by linear interpolation.

5.3.2 Control variables

Income We include the logarithm of GDP per capita and its squared value to control for income ($logIncome$). A higher income is associated with higher ratification probability. The squared value is necessary to account for non-linearity in the relationship between income and environmental preference as described by the Environmental Kuznet Curve (Andreoni & Levinson, 2001). The data on GDP per capita in current USD comes from the UN National account estimates (UNSD, 2017).

Democracy A control for democracy is a constant feature in the empirical works on ratification. This is probably linked to the fact that earlier works emerged in the area of political science and focused on how civil liberties and regime types affect ratification (Congleton, 1992; Fredriksson & Gaston, 2000; Neumayer, 2002a). The results show a significant positive effect on ratification. All the subsequent works in the area include some form of control for this factor. We use Freedom House index of civil liberties (Freedom House, 2017) to control for democracy ($FreedomHouseCL$). The index is expressed on a scale from 1 to 7, where a lower score indicates a higher degree of freedom.

State of the environment Dissatisfaction with the quality of the environment prompts governmental action. On the international stage this translates into higher chances of taking part in environmental agreements. As the agreements in the sample cover different environmental issues, the measure for environmental quality needs to be as general as possible to reflect the broad range of environmental issues involved in the analysis. We decide to use an index on the conservation of species as a proxy for the state of the environment ($ThreatenedSpecies$). Most environmental changes tend to either directly or indirectly affect animal species. Temperature change, habitat disruption, water pollution, poaching, desertification, air pollution and/or deforestation have a devastating impact on animal species. The link between animal species and environmental quality can be used to evaluate the state of the environment. The Red List Index ranges from 0 to 1 and indicates the conservation status of species groups in a territory. A higher risk of extinction is associated with lower scores. The data is sourced from the IUCN website (IUCN, 2017).

Natural capital By natural capital we refer to environmental assets rather than extractive assets. Some countries possess unique ecosystems that are fundamental in maintaining global sustainability. These countries receive more international pressure to ratify, and environmental agreements often facilitate the protection of their natural resources, through aid-transfer and flexibility clauses, in order to secure their participation. These considerations suggest that the question of ratification could be approached differently by environmentally rich nations. The literature postulates a positive relationship between richness in natural resources and participation in international agreements. We control for this factor by including the natural logarithm of the forest area in thousands of squared kilometres ($logForest$)[8].

Regional agreements Regional and global agreements address environmental issues on a different scale. The larger the agreement, the harder is the negotiation phase. Global agreements have to result in a compromise for all nations; which is reflected in their characteristics and in the way they are ratified (Figure 5.8). The difference is accommodated in the model by including a dummy variable ($Regional$) that takes the value of 1 if the treaty is not open to all countries or if the scope of the agreement is regional (see section 5.2.2 for more on this). The variable was coded on the basis of the text of the agreements reported in the IEA Database Mitchell (2017).

Interdependence in ratification dynamics When a treaty is ratified by a country, notably a big one, the ratification probability of other countries is affected. In fact, the higher the number of ratifiers,

[8]Own calculations combining data on land extension (FAO, 2017) and share of territory occupied by forest (World Bank, 2017a).

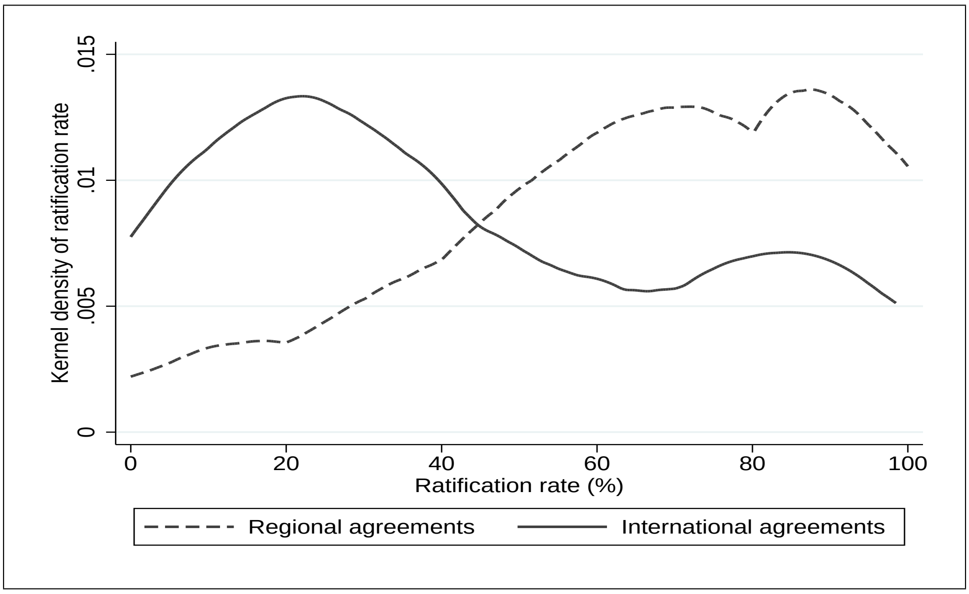

Figure 5.8: *Ratification of regional and global agreements*

Notes: In general, global agreements tend to have a lower turnout than regional ones. Ratification displays a bimodal distribution; agreements are either joined by the majority of countries or just by few because countries' decisions are interrelated (particularly evident for global agreements). The kernel density function provides an approximation of the probability distribution of the ratification rate. The ratification rate is calculated as the number of ratifiers over the number of potential ratifiers up to 2017. For more details on the ratification data see section 5.2.2.

the stronger is the peer pressure on the country that did not ratify. Either by emulation or because of stronger diplomatic pressure, the country has a greater incentive to ratify. Some authors argue that foreign ratification also bears a strong signalling effect on the economic and technical feasibility of the agreement goals. We account for this by including the share of countries in the same region that ratified the agreement ($RatRegion$). This is calculated as the percentage of the potential ratifiers in the same geographic UNSD sub-region[9] that *already* ratified the agreement at time t. By including ratification choices of other countries in the same equation, we create the risk of spatially correlated error terms and simultaneity bias from spatially lagged variable (Sauquet, 2014). For this reason we consider only the ratifications that took place up to time $t-1$. The temporal lag ensures there is no direct causality running back from the explanatory to the dependent variable.

[9]Cf. Appendix A

In fact, there is no way the ratification decision of country A at time t might influence ratification of country B at time $t-1$. Moreover, the ratification status in the previous year is still a relevant variable to capture international influence on domestic ratification choices because treaty ratifications often take several months to get legislative approval. Thus, foreign ratification choices are likely to reflect on domestic policies with a temporal lag. Lagged ratification variables have first been used by von Stein (2008) and became a common practice in ratification studies [10].

Big ratifiers In addition, we also isolate the effect of 5 big ratifiers: United States, Russia (and USSR), China, India and Germany. For each of these a dummy variable is included that takes the value of 1 if the country already ratified at time t and 0 otherwise ($RatUS$, $RatChina$, ... etc). United States and Russia (and USSR) are diplomatic superpowers, a ratification by any of these is very likely to trigger the ratification of other countries in their respective sphere of influence. Similarly, China and India are two rising powers. Because of their size and population their participation is decisive for the success of environmental agreements. Finally, Germany is chosen because after the creation of the EU, European countries tend to ratify environment agreements as a "bloc". Hence, the dummy for German ratification is a proxy for European participation to the agreement. Table 5.2 illustrates the correlation among the ratifications of some key nations; European countries generally exhibit higher correlation among them than with other nations as illustrated by the coefficients for the United Kingdom, France and Germany.

It must be noted that for some countries the ratification choice of the big ratifiers might enter twice in the equation. If India ratifies an agreement, the effect of its ratification will affect all the countries in the world through the dummy $RatIndia$ and additionally affect Southern Asian through the variable $RatRegion$. As a result, although the variables are not collinear, the correlation between the two variables increases. This might make it harder to isolate the effect of India's ratification from the overall regional effect, but the estimates should not be biased in principle. Also, the five big ratifiers are not in the same geographic sub-region; hence, their effects do not cumulate.

[10]Among others, they are used by Bernauer et al. (2010), Leinaweaver (2012), Schneider & Urpelainen (2013), Bernauer et al. (2013a), Yamagata et al. (2013), Sauquet (2014), Schulze (2014), Böhmelt et al. (2015), Mohrenberg et al. (2016), Spilker & Koubi (2016), Yamagata et al. (2017), and Hugh-Jones et al. (2018).

Table 5.2: *Correlation matrix for ratification variables — post 1990*

	1	2	3	4	5	6	7	8
1. RatRegion	1.000							
2. RatUS	0.221	1.000						
3. RatChina	0.332	0.461	1.000					
4. RatRussia	0.259	0.286	0.278	1.000				
5. RatIndia	0.487	0.407	0.446	0.275	1.000			
6. RatGermany	0.364	0.272	0.360	0.444	0.537	1.000		
7. RatFrance	0.341	0.440	0.427	0.434	0.446	0.661	1.000	
8. RatUK	0.392	0.443	0.467	0.378	0.618	0.672	0.583	1.000

Framework agreements Framework agreements are treaties that set general principles, guidelines, or goals, but only weak or non-binding targets or obligations. We expect non-binding treaties to receive a higher number of ratifications. Therefore, we introduce a dummy ($FrameworkAgreement$) that takes the value of 1 if the agreement is a framework agreement according to the sequence classification of the IEA database (Mitchell, 2017).

5.3.3 Missing observations and sampling bias

Our data set on ratification of environmental treaties covers the period 1950-2017 for almost 200 countries. This chapter has detailed how attention has been paid to ensuring that all nations are adequately included in the study in order to obtain a sample of nations as close as possible to the entire population. Similarly, the sample of treaties is as large as possible and we intentionally include regional agreements because they have an important weight in environmental diplomacy. In the course of the empirical analysis we use just a subset of our ratification data set, primarily because of global political shifts and because of problems linked to missing observations for some of the explanatory variables. In this section, we discuss these two issues in more depth.

The focal point of the analysis is to understand the ratification of environmental treaties. Yamagata et al. (2017) drew attention to how the fall of the communist block entailed a shift in international politics, with major changes in how ratification is approached by sovereign nations. In econometrics this is termed a structural break. We could account for the structural break in different ways, but unfortunately the data available in the pre-1990 period is not as complete as the post-1990. For this reason, it is prudent to restrict the analysis to the post-1990 period. Moreover, modern ratifications are a better basis for understanding current environmental diplomacy.

The problems linked to data availability are essentially of two types: *i*) missing values, and *ii*) missing country series. Regarding the first point, some of our explanatory variables have a shorter time coverage. For example, while data on income is easily available from 1970, the index on the quality of institutions or the proxy for industrial pressure are only consistently available from the 1990s. In the post-1990 period we have generally very few missing values for our set of variables. Therefore, focusing on the post-1990 period allows us to put together a more complete panel of data.

With reference to the second point, missing country series have potentially bigger consequences. In fact, the problem is that the data is not missing in a random fashion; typically the countries with missing data have similar characteristics. They tend to be smaller nations, less developed and/or with special political situations. The risk associated with such missing observations is to incur into sampling bias because specific groups of countries are systematically excluded from the sample of nations. As a consequence, the estimates are no longer valid for the entire population. We therefore limit the impact by selecting indicators available for as large a number of nations as possible. In the end, only the following countries are excluded because of missing observations in the independent variables: the Holy See, North Korea, Nauru, Monaco, San Marino, Kosovo, South Sudan. The exclusion is clearly not random, the countries for which data is not available tend to be small or with peculiar institutional characteristics. We argue that the exclusion of these countries has a negligible impact on the final estimates.

Firstly, the Holy See has a special status. It is a fully independent nation capable of ratifying treaties, but its religious status entails that international relations are approached rather unconventionally. They often strive for impartiality on political decisions as shown by the fact that they refused a seat at the UN and opted for an observer status. Likewise, Monaco and San Marino have their own peculiarities. While they are sovereign nations, their security is guaranteed respectively by France and Italy. They depend economically and diplomatically on their surrounding neighbours and as such their international policy is mostly dictated by France and Italy. Kosovo and South Sudan are the two youngest states. The first was created in 2008 and the latter in 2011. They are both politically unstable, which explains the lack of collected data. In the case of North Korea, political isolation is responsible for the lack of data. Finally, Nauru is a small island in the South Pacific Ocean. The country is known for having few and unreliable official statistics (CIA, 2017). Their economy is dependent on the export of phosphate and the depletion of its mineral resources is making the state increasingly dependent on Australian financial aid.

All these nations have very precise reasons for lacking observations. There is no systematic pattern to their missing observations. Unfortunately there is no way of compensating the missing data with supplementary data or circumventing the problem by other means. Nevertheless, the effect of these omitted countries should be negligible overall. They only account for a very small portion of the total observations and our sample still contains 190 countries, which is almost the totality of sovereign nations in the world. Since our sample almost matches the entire population we are confident that the effect of the excluded units is inappreciable on the final estimates, and more importantly, the estimates of the model remain reliable for the population of countries and are generalisable beyond our sample of treaties.

In summary, the data on participation in environmental agreements goes back to 1950 but we choose to start the analysis from 1990 to avoid any problem linked to missing observations and structural shifts in international politics. Starting in 1990 also allows us to have an almost perfectly balanced panel data. The panel is *almost* balanced because some countries came into existence after 1990: e.g. Montenegro and Slovakia. Notwithstanding, for the period 1990-2015 we still have more than 200000 usable observations on ratification. In this section we argued that despite the omission of 5 nations from the analysis the resulting estimates should remain valid for the entire population.

Table 5.3: *Summary statistics — post 1990*

Variable	Obs.	Mean	SD	Min	Max
Country variables					
$ENGO$	5224	4.849	8.086	0	62
$ResourceRent$	4732	7.611	11.961	0.000	89.166
$Institutions$	4732	-0.060	0.997	-2.174	2.470
$logIncome$	4776	8.009	1.622	4.388	12.142
$FreedomHouseCL$	4976	3.430	1.869	1	7
$ThreatenedSpecies$	4616	0.875	0.089	0.404	0.995
$logForest$	4463	7.422	2.815	-1.514	13.652
Treaty Variables					
$Regional$	263	0.722	0.449	0	1
$FrameworkAgreement$	263	0.717	0.451	0	1
Ratification variables					
$RatRegion$	254350	0.128	0.211	0	1
$RatChina$	254350	0.269	0.444	0	1
$RatGermany$	254350	0.519	0.500	0	1
$RatIndia$	254350	0.303	0.460	0	1
$RatRussia$	254350	0.08	0.271	0	1
$RatUS$	254350	0.381	0.486	0	1
$Ratification$ (dependent)	254350	0.025	0.155	0	1

Chapter 6

Results on the ratification of environmental agreements

In this chapter we present the main results of the analysis. The model we develop is used to study the determinants of ratification, with a special focus on the effect of environmental and industrial lobbying as well as the role played by institutions in fostering participation to environmental agreements. The results are used to derive important conclusions on the main determinants of ratification and on how lobbying practices are exerted. The chapter is structured as follows. The first part of the chapter is dedicated to the discussion of the results. In the second and third section we evaluate the convergence of the parameters and the robustness of the findings. The fourth section summarises the main findings and draws important policy implications. Finally, the last section applies the model to different treaties and countries to illustrate a few practical applications of the model.

6.1 Main results

In table 6.1 we report the main results on the ratification of environmental agreements. Five different model specifications are presented (model I to V). The first two are the reference specifications of the study, the estimates correspond to the mean of the marginal posterior distributions which are also presented in terms of hazard ratios[1]. 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 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. A description of all the variables used in the model can be found in appendix C. All models are estimated with MCMC, as described in chapter 5. The estimates presented in this chapter are asymptotically equivalent to maximum likelihood estimates. This property is derived from the Bernstein–von Mises theorem, which posits that — with large enough data, full parametrisation of the model and uniform priors — the posterior distribution of the parameters approaches a normal distribution centred upon the maximum likelihood estimate (Nickl, 2013). Hence, for the purpose of frequentist asymptotic inference, this implies that MCMC yields identical results to the ones obtained with the asymptotic distribution of the maximum likelihood estimator. In other words, this means that the estimates derived from the posterior distribution can be directly compared to a "classic" frequentist estimate.

Environmental and industrial lobbying

To begin with, we find that environmental lobbying has a positive and significant effect on the probability of ratifying. An 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[2]. The positive effect of environmental lobbying is in line with other results in the literature (e.g. Fredriksson & Ujhelyi 2006, von Stein 2008, Bernauer et al. 2013a). On the other

[1] All other things being equal, a hazard ratio higher than 1 indicates an increase in the probability of ratification while a hazard ratio between 0 and 1 suggests a reduction in the probability 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 in 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 made with having a unit increase in the variable. In Model I, the hazard ratio for $Regional$ has a value of 2.370. This implies that ratifications occur 2.370 times more often in regional treaties than in global ones.

[2] In model II 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.

Table 6.1: *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.

hand, the results for industrial lobbying are in sharp contrast with our hypothesis on the impact of lobbying. In fact, industrial lobbying is not statistically significant in any of the five specifications of table 6.1. 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 the next section, where — among other things — different measures for industrial lobbying are tested to verify the robustness of our estimates.

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 has a multiplicative effect of 8% on the baseline hazard of ratification. Institutions have a positive effect on the participation in environmental agreements and the result is consistent across the five specifications of table 6.1. In addition to that, Model I indicates that the effect of ENGO's lobbying is stronger when the quality of institutions 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 situations. 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. Both arguments imply that environmental lobbying is an effective tool to stimulate participation of countries with less developed institutions because of the higher marginal effect of lobbying.

Table 6.2 shows that our measure for the quality of institutions exhibits a non-trivial degree of correlation with $logincome$ (0.736) and $FreedomHouseCL$ (-0.681). Richer nations tend to have better institutions and 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 not statistically significant[3]. The inclusion of *FreedomHouseCL* and *logIncome* does not affect the consistency of the estimates.

Table 6.2: *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. In fact, environmental agreements often include facilitating measures, technical assistance, and financial aid to developing nations that decide to take part to the agreement. According to the principle of *common but differentiated responsibilit-*

[3]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 correct 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.

ies 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. Nonetheless, in model III, where $AnnexI$ is used to proxy for both the level of development and expected environmental commitment, the effect is positive and strongly significant. This could indicate that tighter obligations for developed nations do not necessarily offset the positive effect on ratification associated with a higher level of economic development.

Democratic states tend to engage more in environmental agreements; a lower score in the $FreedomHouseCL$ index is significantly linked to higher chances of ratifying in all models. This result corroborates the already established, and widely accepted, relationship between democracy and ratification of environmental agreements. In fact, several empirical works have already demonstrated that democracies are more likely to join environmental agreements (e.g Congleton 1992, Neumayer 2002a).

Natural capital

The quality of the environment — proxied by $ThreatenedSpecies$— is positively correlated with ratification, but the estimates hardly reach a significant level; the coefficient is significant at the 10% level only in model I. Many forms of degradation of the environment do not entail a response under the form of international cooperation, very often countries may prefer to tackle them domestically and unilaterally. On the other hand, the richness in natural capital seems to matter for ratification; having a large forest area ($logForest$) is always significantly associated with a higher probability of ratifying environmental agreements. We conclude that countries that are rich in environmental capital are more likely to get involved in environmental agreements with their neighbours and are also more likely to ratify treaties that aim at protecting their environmental assets. If environmental agreements are considered international public goods preserving environmental assets, then countries with larger forest areas are capable of capturing a higher share of the benefits derived from the treaty. All things considered, a country rich in environmental assets has a higher propensity to ratify environmental agreements.

International interactions

Besides domestic characteristics we find that an important part of ratification decisions is explained by the actions of foreign countries. The game theoretical literature on participation in environmental agreements stresses that the decisions of different countries are strategically linked. Our findings strongly support this contention. If all geographic neighbours ratify the treaty, the baseline hazard of ratification is multiplied by as much as 80% (Model I). Furthermore, the ratification decisions of big countries heavily influences the likelihood of ratification by other nations. In particular, ratification by China, Germany (proxy for the EU), and India increase the chances of ratifying a treaty. On the contrary, when Russia or the Unites States ratify the hazard of ratification decreases. These results could be explained by the polarising effect that Russia and United States have. Despite the fall of the Soviet Union, both countries still have a competing area of 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 ratification by China 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 in bloc. Hence, the positive coefficient of *RatGermany* is in part linked to the correlation among European ratifications.

Regional agreements and treaty characteristics

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 its likelihood of being ratified. On average, the hazard of ratification of a regional agreement is 2.37 times the one 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 hard and could end up penalising the participation in the treaty or the effectiveness of the agreement. It has been suggested that participation by a large number of countries is only achievable by watering-down the content of the agreement (Barrett, 1994). Regarding the supposed trade-off between the strictness of the agreement and the level of participation, our results are encouraging. We observe that framework agreements, which generally state principles rather than imposing strict obligations, are not significantly linked to higher ratification probabilities. Model III also indicates that on a large sample of treaties annex I countries are not generally associated with reduced probabilities of ratification. Overall, these results suggest that it is possible to achieve a good rates of participation and at the same time a meaningful level of environmental protection. Nevertheless, the set-up of our analysis does not allow to draw definitive conclusions on this aspect of environmental agreements.

The random part of the model shows that most of the variation is explained by heterogeneity at the level of the treaty, which greatly exceeds the impact of unobserved country characteristics. Differences among treaties are the fundamental cause of disparities in ratification. This result is not surprising, the success or failure of a treaty depends chiefly on the content of the agreement and only secondarily on country characteristics or strategical interaction. All of this emphasises the importance of multilevel approach for modelling treaty ratification; given the profound difference existing between treaties, it is necessary to account for heterogeneity among treaties in order to ensure correct estimates. Thus, from a methodological perspective, this study constitutes an important improvement over previous empirical literature which often fails to account for the individuality of treaties.

Additional comments

Finally, The cubic polynomial of time captures the time dependency of ratification. The probability of ratifying initially increases with time, but the negative quadratic term makes ratification after several years very unlikely. Some simple algebra reveals that, conditional on the other variables, the maximum hazard of ratification is reached roughly around the end of third year from the opening to ratification. Thereafter, the likelihood of ratification decreases as a result of the "cooling down" of the treaty. This result closely matches what is commonly observed in the timings of ratification, where most of ratifications tend to concentrate in the first years following the opening to ratification.

Model IV is a simplified version of model I. The dummy variables for the big ratifiers are omitted, but $RatRegion$ is still present to control for the ratification of neighbouring nations. We do not include the interaction term between the quality of institutions and lobbying variables and only keep $ThreatenedSpecies$ as control for differences in environmental quality. Even with this reduced specification the estimates of our main variables seem stable and do not substantially differ from Model I. Last but not least, Model V is the same model as model I but estimated exclusively on a sample of global agreements. We find that the effects of environmental and industrial lobbying are the same as in the full sample and the quality of intuitions still displays a positive effect on ratification. All of this demonstrates that, after identifying all the potential ratifiers in regional agreements, the estimates obtained on the full sample are not noticeably different from global treaties alone. Regional agreements have a higher probability of ratification than global agreements, but country characteristics affect both types of treaties in the same way.

Summary

In summary, environmental lobbying has a positive effect on the ratification of environmental agreements, while the effect of industrial lobbying is not significant. This result is perplexing; industrial lobbies usually possess much larger economic means than environmental lobbies and, given their interest in the outcome of environmental treaties, we would expect a negative impact on ratification. In the next section, we will test other proxies for industrial lobbying to assess whether this finding is linked to the specific measurement we employ for industrial lobbying or whether it is robust to changes in the choice of variables. Besides all this, our findings indicate that institutions play an important role in promoting international cooperation on environmental issues. Countries with better institutions tend to ratify more environmental agreements. Furthermore, we find that the effect of ENGOs augments in the presence of lower quality institutions. Corrupt institutions do not channel demand for environmental protection effectively. In this context, environmental lobbying becomes a more effective tool to apply pressure on ratification choices. The last finding echoes the results of Bernauer et al. (2013a) and Fredriksson et al. (2007) on the relationship between the effectiveness of lobbying and institutional factors.

Table 6.3: *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.

6.2 Trying different measurements for industrial lobbying

In the previous section we explained how the results for industrial lobbying contrast the theoretical expectations formulated in chapter 4. In this section, we test different proxies for industrial lobbying to assess the robustness of our findings and check if different measurements yield the same counter-intuitive result. After all, our proxy is an imperfect measure for lobbying activity, which is notoriously hard to quantify. As far as we know, there is no reliable data tracking industrial lobbying. Hence, in this section, we experiment with different proxies to evaluate whether the results we obtained depend from the specific proxy choice. In table 6.3 we report the results obtained with 4 additional measures for industrial lobbying. The 4 new proxies are $EnergyUse$, $ShareIndustry$, $IMFresourcerich$ and $FossilExports$. Hopefully, these should allow to diversify the perspective of the analysis and ensure that it is not driven by idiosyncratic factors in the proxy.

Table 6.4: *Correlation matrix for industrial lobbying proxies*

	1	2	3	4
1. EnergyUse	1.000			
2. ShareIndustry	0.217	1.000		
3. IMFresourcerich	−0.063	0.399	1.000	
4. FossilExports	0.156	0.582	0.692	1.000
5. Institutions	0.593	−0.151	−0.370	−0.289
6. logIncome	0.697	0.067	−0.270	−0.077
7. FreedomHouseCL	−0.282	0.362	0.422	0.457
8. ThreatenedSpecies	0.237	0.101	−0.005	0.116
9. logForest	−0.216	0.012	0.104	−0.021

$EnergyUse$ 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. Some works that use this measure include: Yamagata et al. (2013), Yamagata et al. (2017), Sauquet (2014) and von Stein (2008). The main limitation of this proxy is that it mainly reflects the economic paradigm and development stage of the country rather than lobbying strength. However, in its defence, it could be argued that industrial interests carry more weight and are more likely to be attended if the industrial compartment accounts for a larger share of the economic activity of the country. $IMFresourcerich$ is a dummy variable that takes the value of 1 if the country is rich in natural resources according to the IMF (2012). This variable mainly takes into account 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. Both Fredriksson & Ujhelyi (2006) and Neumayer (2002a) use a variable similar to $IMFresourcereich$ based on whether or not a country is a "fuel" exporting country. The last proxy is $FossilExports$, which is calculated as the share of fossil fuels in the export basket. Fossil industry is chosen because it is one 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 6.3 are globally stable and the coefficients are consistent with the ones in model I–V. However, the 4 different variables we test in this section yield very inconclusive findings on the impact of industrial lobbying. $EnergyUse$ and $IMFresourcerich$ do not appear to be significant, just like $ResourceRent$. 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 whereas a higher share of manufacture, mining and utilities in the GDP increases the likelihood of ratification. Table 6.4 shows the correlation of the four new proxies with the explanatory variables of the model. The only salient correlation is the one between $EnergyUse$ and $logIncome$. Despite a correaltion of 0.7, we notice that the estimates for $logIncome$ and the effect of industrial lobbying tend to be consistent with the results of the other proxies. Overall, these results do not provide evidence of a negative impact of industrial lobbying on the ratification of environmental agreements.

A comprehensive 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 6.5 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 6.5: *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: dummy for members in the World Business Council for Sustainable Development, numbers of vehicles per capita, 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	2 specifications for the UNFCCC and 2 specifications for the Kyoto Protocol; industrial lobbying never reaches significance
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).

Industrial lobbying in the empirical literature (continued)

Paper	Proxies	Results
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. Only in very few cases industrial lobbying has a statistically significant relationship with the ratification of environmental agreements. The majority of the times an insignificant effect is found. The analysis of the literature confirms that our findings are consistent with previous studies. The evidence from the literature does not support the existence of a relationship between the intensity of industrial lobbying and the likelihood of ratification. Even in widely different studies, with different models, specifications and different samples of countries and treaties, the findings are consistent: industrial lobbying, no matter how it is measured, is not significantly linked to lower probabilities of ratifying environmental agreement. In summary, Industrial lobbying has no clear effect on ratification and this is not due to the specific proxy we use.

In this section, we ruled out the hypothesis that *Resourcerent* was leading to wrong conclusions by testing several alternative proxies for industrial lobbying. Not only is our result stable, but we also find that the models estimated in other studies lead to the same conclusions on the effect of industrial lobbying. The absence of a relationship is in itself perplexing and contrary to theoretical expectations. The reasons for this counter-intuitive result have never been adequately explored, and this constitutes a gap in the literature. 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 suggest that, in general, industrial lobbies prefer to target the implementation phase rather than the ratification of environmental agreements. This thesis will be explored in the next chapter, where we will attempt to verify this assertion by evaluating the impact of lobbying on different environmental domestic policies.

6.3 Convergence and robustness checks

In the previous sections we discussed the main findings on the ratification of environmental agreements. We have found that environmental lobbies and the quality of institutions have a positive impact on ratification and these two effects interact. The impact of an additional ENGO is reduced when the country possesses good institutions. On the other hand, industrial lobbying is not significantly associated with lower probabilities of ratification. In this section, we assess the robustness of the results by checking fundamental assumptions of the model. In the first part of the section we provide evidence that the sampled distribution has converged while in the second half we experiment with a diverse range of specifications to test the stability and validity of our findings.

6.3.1 Convergence

In this section we discuss the convergence of the reference model (Model I). A theoretical property of MCMC is that — independently from the starting values or complexity of the model — the distribution of MCMC chains are bound to converge on the target distribution after an infinite number of iterations. However, as the number of feasible iterations is finite, the question of whether or not the estimation has converged is fundamental to statistical inference.

Table 6.6 reports a series of statistics that are used to assess the convergence of the chains. The first three columns present the mean, median and mode of the marginal posterior distributions. In MCMC estimation all of these measures are commonly used for inference. The matching of median, mean and mode hints to the fact that the generated samples are normally distributed and suggest that the Markow Chains have converged. For all of the parameters of the model the mean, median and mode converged toward the same value lending a

Table 6.6: *Convergence statistics for model I*

	Mean	Median	Mode	ESS	RL 2.5%	RL 97.5%	BD
$ENGO$	0.021	0.021	0.021	7712	34 890	36 648	12 792
$ResourceRent$	0.004	0.004	0.005	22 193	40 824	40 880	180 932
$Institutions$	0.098	0.098	0.098	18 287	42 696	45 664	366 395
$ENGO.Institutions$	−0.008	−0.008	−0.008	8870	34 570	36 038	535 418
$Resourcerent.Institutions$	0.003	0.003	0.003	25 073	41 272	39 856	108 403
$logIncome$	0.207	0.207	0.208	22 457	41 736	41 968	32 477
$logIncome^2$	−0.011	−0.011	−0.011	22 714	42 664	42 824	12 551
$FreedomHouseCL$	−0.129	−0.129	−0.129	24 221	24 342	23 462	480
$ThreatenedSpecies$	0.590	0.589	0.587	8147	36 246	37 898	675 411
$logForest$	0.055	0.055	0.055	7842	41 578	40 772	92 843
$RatRegion$	0.590	0.590	0.591	47 753	33 800	33 808	2790
$RatUS$	−0.714	−0.714	−0.714	18 307	43 784	43 368	6558
$RatChina$	0.361	0.361	0.361	33 000	37 656	34 504	3479
$RatRussia$	−0.199	−0.199	−0.198	18 056	25 222	25 426	30 591
$RatIndia$	0.254	0.254	0.253	39 846	34 608	34 784	2810
$RatGermany$	0.325	0.325	0.324	33 227	38 056	36 792	2732
$Regional$	0.863	0.862	0.864	533	92 810	119 068	1 231 190
$FrameworkAgreement$	0.171	0.171	0.169	901	121 388	101 160	1 599 008
t	0.041	0.041	0.041	37 539	35 488	35 608	7458
t^2	−0.006	−0.006	−0.006	34 421	37 144	35 936	2262
t^3	0.000	0.000	0.000	36 620	36 728	37 272	4393
$cons$	−5.643	−5.642	−5.644	8968	49 464	50 312	12 949
Variance *treaty* level ($\sigma_{u_{j_1}}$)	2.584	2.563	2.537	79 637	31 656	31 856	303
Variance *country* level ($\sigma_{u_{j_2}}$)	0.239	0.237	0.235	98 590	30 448	31 136	247

Total iterations	800000	Burnin	300000
Stored Chain length	250000	Thinning	2

Notes: ESS is the Effective Sample Size statistic. ESS assesses the chains on the base of their correlation. “RL 2.5%” and “RL 97.5%” are the Raftery-Lewis statistics (Raftery & Lewis, 1992) for the 2.5% and 97.5% percentiles. The Raftery-Lewis statistcs are estimated for a margin of error of 0.005 with a probability of 95%. “BD” is the Brooks-Draper statistic; it is calculated for $k = 2$ significant figures and a significance level of $\alpha = 0.05$.

case in favour of convergence. The only exceptions being the variance parameters of the treaty and country effects. As a matter of fact, the posterior distribution of variance parameters is typically right skewed as illustrated by the histograms in figure 6.1. The value of the median is comprised between the mean and the mode due to the light skewness in the distribution.

The effective sample size (ESS) is one of the most popular statistics to assess the efficiency of the sampling algorithm. It quantifies the number of independent samples generated during estimation. A higher ESS indicates that the samples are less correlated. Unfortunately, multilevel models for survival data are complicated to estimate, as chains are highly correlated and typically do not mix well (Steele et al., 2004). We follow the advice of Browne et al. (2009) and use orthogonal parametrisation which considerably improves chain mixing. Given the type of data, we obtain a reasonable ESS. *Regional* and *FrameworkAgreement* exhibit the lowest ESS because of the small amount of independent observations compared to variables at the country and ratification level. For *Regional* and *FrameworkAgreement* the effective variability is much lower than for other variables. Since they are not time-varying, the only variability is across treaties. The actual number of observations is around 250 independent observations. This is much less than country variables which have approximately 5000 country-year combinations for the post-1990 period, and even less than variables at the ratification level which can rely on observations from more than 200000 separate treaty-country-year dyads. Given the limitations associated with the type of data and the available information on treaties, we postulate that the ESS results are satisfactory.

Estimation of multilevel survival models with MCMC notoriously yields highly correlated chains (Browne et al., 2009). For this reason we opt for a very high number of iterations. In total we perform almost one million iterations, out of which we discard one every two samples, for a total of 550000 samples generated. This practice is called "thinning" and is used to reduce the autocorrelation in the chains. We also choose a very long burn-in period. In fact, we discard the initial 300000 out of 550000 samples to make sure the inference is based on a chain that has converged. Likewise, the number of iterations has been selected in an overly prudent fashion in order to base inference on a number of samples as large as possible. The large number of samples allows more precise estimates for the coefficients of the model.

As a supplementary graphical check, in figure 6.2 we present traces of the last 20000 iterations of the MCMC estimation. These traces show that the chains seem to have converged around a mean and that they explore efficiently the joint distribution. Healthy trace plots resemble a white noise process, with a constant mean and variance. We also notice that *Regional* and *FrameworkAgreement* mix less efficiently

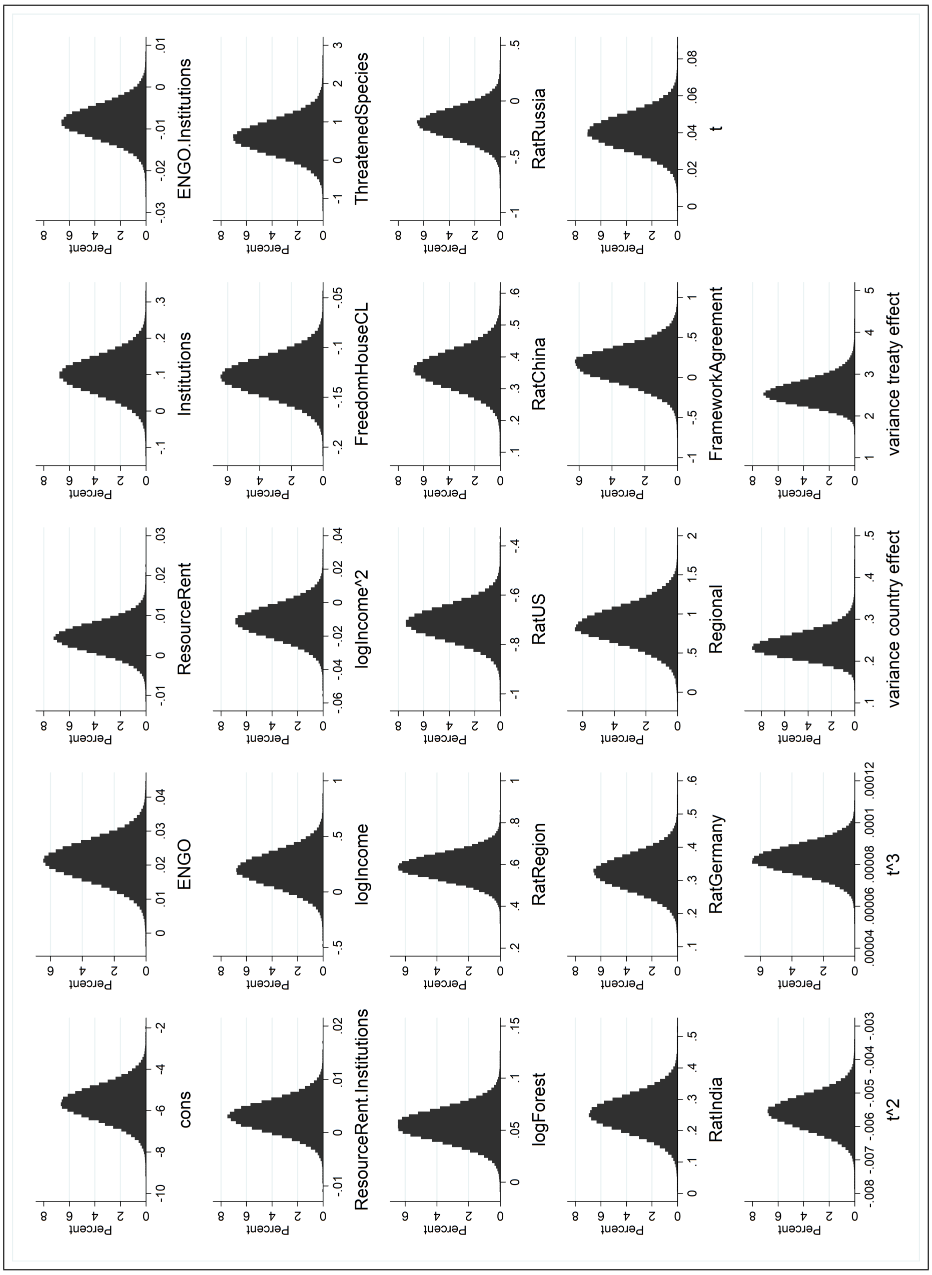

Figure 6.1: *Marginal posterior distributions*

Notes: Histograms for the distributions of the 24 chains of model I. The densities of MCMC chains are estimates of the marginal posterior distributions. As expected, the parameters of the model are normally distributed while the variance parameters are slightly skewed, with a longer right-tale.

than other chains, but well enough considered the available information on treaties. Overall, the traces seem to indicate that the chains have converged and that the algorithm is mixing well.

Additional diagnostic statistics are reported in the last columns of table 6.6. The Raftery & Lewis (1992) statistic gives information on the number of iterations needed to yield estimates of the 2.5 and 97.5 percentile, which together form an interval containing 95% of the distribution. This statistic is used as a diagnostic to assess convergence and also measures the precision of quantile estimates from the posterior distribution. The Raftery-Lewis statistic is known to be conservative and usually suggests more iterations than necessary (Browne, 2004). If the statistic is satisfied the actual quantile distribution (0.025,0.975) of the parameter should be less than 1% different from the estimated probability. All our chains satisfy the Raftery-Lewis diagnostic.

Finally, the Brooks-Draper diagnostic is a statistic for the mean of the posterior distribution. It estimates the iterations required to achieve estimates of the mean with a given level of significance and a desired number k of significant figures. In the last column of table 6.6 we report the number of iterations needed to quote mean estimates with a precision of 2 significant figures and a confidence level of 95%. For example, the Brooks-Draper statistic for the parameter of $ENGO$ implies that 12792 iterations are needed to express the mean estimate "0.02" with 95% of confidence; we run a total of 800000 iterations, well above the recommended number. The only two parameters for which the recommended level is not reached are $Regional$ and $FrameworkAgreement$; again, given the lower number of independent observations, it is harder to obtain high levels of precision for these parameters. Nevertheless, if the test is run with $k = 1$ the chains satisfy the requirements of the Brooks-Draper diagnostic; in fact, the Brooks-Draper statistic for $FrameworkAgreement$ is 15991 and 12312 for $Regional$ when $k = 1$.

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 explores the entire joint distribution. We experiment with 5 different starting points. The starting values are obtained by multiplying the vector of starting values of Model I by a scalar taking the values of -1, 0, 2, 3, and 4. The starting values of Model I were obtained by fitting a simplified version of the model that does not take into account the cross-classification in random effects with a maximum likelihood method (IGLS)[4]. The res-

[4]The starting values for the fixed part of Model I are: 0.0171443, 0.0048971, 0.1881271, -0.0116787, 0.0027066, 0.3452093, -0.0196376, -0.0938002, 0.3799708, 0.0635263, 0.432282,

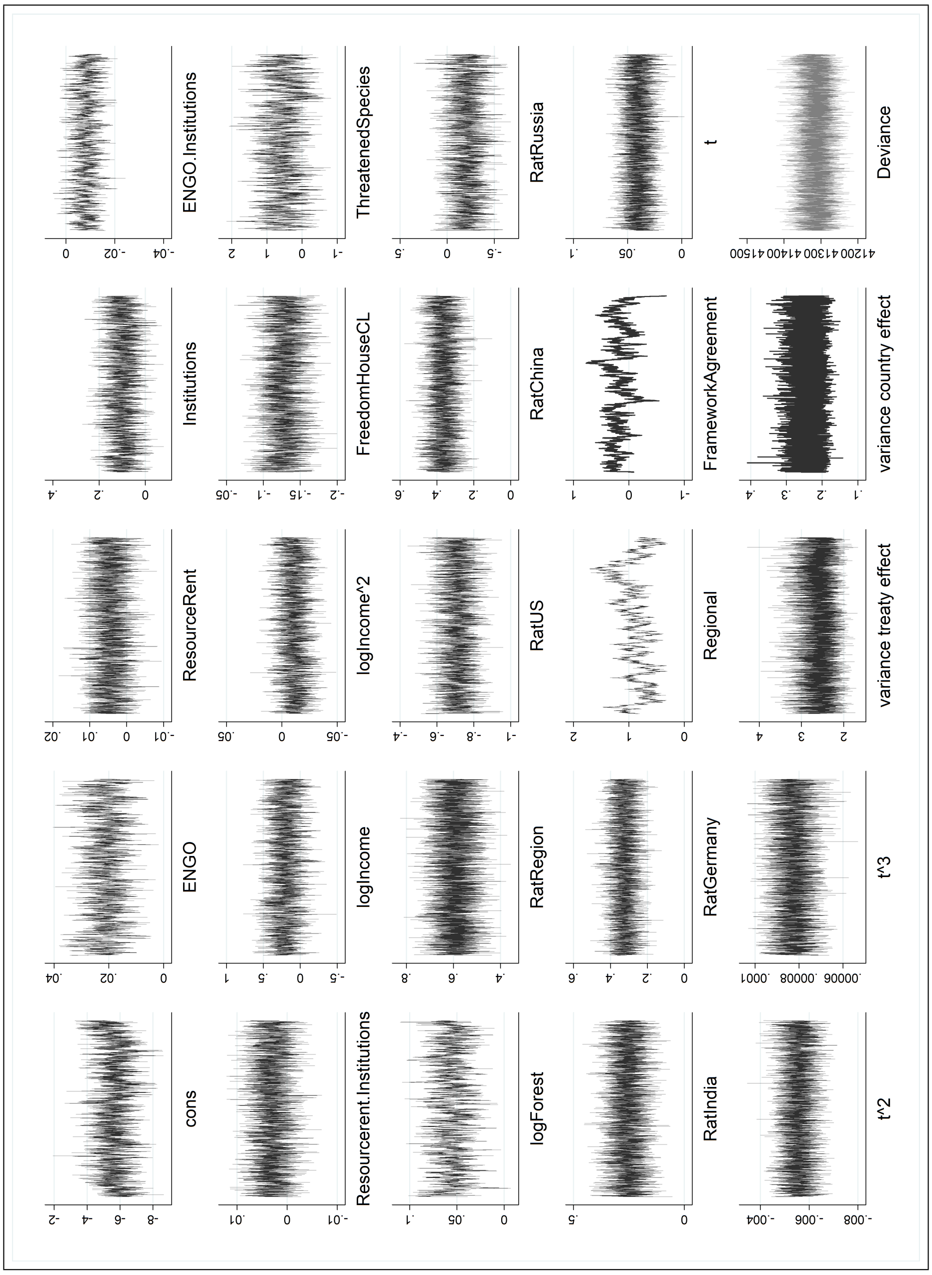

Figure 6.2: *Parameter traces for model I*

Notes: The traces illustrate the last 20000 iterations of the MCMC estimation. They are commonly used to assess convergence and mixing of the chains. Traces that look like white noise processes indicate that the sampling algorithm moves efficiently through the distribution and that the chains have converged around a high probability region.

Table 6.7: *Convergence from different starting points*

	Model C1		Model C2		Model C3		Model C4		Model C5	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
ENGO	0.021***	(0.006)	0.021***	(0.006)	0.021***	(0.006)	0.021***	(0.006)	0.021***	(0.006)
ResourceRent	0.004	(0.004)	0.005	(0.004)	0.004	(0.004)	0.005	(0.004)	0.005	(0.004)
Institutions	0.100**	(0.050)	0.097**	(0.051)	0.098**	(0.051)	0.098**	(0.050)	0.098**	(0.050)
ENGO.Institutions	-0.008**	(0.004)	-0.008**	(0.004)	-0.008**	(0.004)	-0.008**	(0.004)	-0.008**	(0.004)
Resourcerent.Institutions	0.003	(0.003)	0.003	(0.003)	0.003	(0.003)	0.003	(0.003)	0.003	(0.003)
logIncome	0.205*	(0.154)	0.207*	(0.155)	0.203*	(0.152)	0.210*	(0.155)	0.203*	(0.152)
$logIncome^2$	-0.011	(0.010)	-0.011	(0.010)	-0.011	(0.010)	-0.012	(0.010)	-0.011	(0.010)
FreedomHouseCL	-0.129***	(0.019)	-0.129***	(0.019)	-0.129***	(0.020)	-0.129***	(0.019)	-0.129***	(0.019)
ThreatenedSpecies	0.597*	(0.437)	0.590*	(0.440)	0.588*	(0.448)	0.601*	(0.438)	0.590*	(0.437)
logForest	0.055***	(0.015)	0.055***	(0.015)	0.055***	(0.015)	0.055***	(0.016)	0.055***	(0.016)
RatRegion	0.591***	(0.063)	0.590***	(0.063)	0.590***	(0.063)	0.590***	(0.063)	0.591***	(0.063)
RatUS	-0.711***	(0.069)	-0.711***	(0.069)	-0.712***	(0.069)	-0.713***	(0.069)	-0.714***	(0.069)
RatChina	0.361***	(0.058)	0.361***	(0.058)	0.361***	(0.057)	0.360***	(0.058)	0.361***	(0.058)
RatRussia	-0.197*	(0.134)	-0.196*	(0.133)	-0.198*	(0.133)	-0.199*	(0.132)	-0.199*	(0.133)
RatIndia	0.254***	(0.058)	0.253***	(0.058)	0.253***	(0.058)	0.255***	(0.058)	0.254***	(0.057)
RatGermany	0.323***	(0.052)	0.324***	(0.053)	0.325***	(0.052)	0.324***	(0.053)	0.324***	(0.052)
Regional	0.892***	(0.220)	0.907***	(0.236)	0.889***	(0.220)	0.842***	(0.239)	0.906***	(0.236)
FrameworkAgreement	0.158	(0.231)	0.170	(0.224)	0.141	(0.235)	0.165	(0.226)	0.150	(0.229)
t	0.041***	(0.010)	0.041***	(0.010)	0.040***	(0.010)	0.041***	(0.010)	0.041***	(0.009)
t^2	-0.006***	(0.000)	-0.006***	(0.000)	-0.006***	(0.000)	-0.006***	(0.000)	-0.006***	(0.000)
t^3	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)
cons	-5.660***	(0.806)	-5.689***	(0.815)	-5.629***	(0.815)	-5.650***	(0.835)	-5.652***	(0.800)
Random part										
Variance *treaty* level	2.577	(0.304)	2.587	(0.305)	2.584	(0.306)	2.587	(0.305)	2.589	(0.306)
Variance *country* level	0.239	(0.031)	0.239	(0.030)	0.239	(0.031)	0.239	(0.030)	0.239	(0.030)
Units: *treaty*	257		257		257		257		257	
Units: *country*	190		190		190		190		190	
Obs: *ratification*	219266		219266		219266		219266		219266	
k	-1		0		2		3		4	
DIC:	41707.30		41707.34		41706.98		41707.58		41707.47	
Burnin:	200000		200000		200000		200000		200000	
Chain Length:	150000		150000		150000		150000		150000	
Thinning:	2		2		2		2		2	

Notes: ***, ** and * indicate one-tailed Bayesian p-values respectively lower than 0.01, 0.05 and 0.10. Estimates for the same model with different starting values. The starting values are obtained by multiplying the vector of starting values of Model I by the scalar k. The starting values of Model I are obtained by fitting with IGLS a simplified version of the model that does not take into account the cross-classification in random effects.

ults are reported in table 6.7, they display consistent estimates even with different starting values. Using different starting points allows us to rule out pseudo-convergence — that is to say, the convergence towards a local point of high probability. This is particularly dangerous in multimodal distributions.

Overall the Raftery-Lewis and Brooks-Draper diagnostics suggest that we have run the MCMC simulation for long enough to achieve a stable convergence. Notwithstanding, for $FrameworkAgreement$ and *Regional* the estimates should be quoted with a lower level of precision to guarantee the same confidence level. The traces of the chains suggest that the algorithm is mixing well and explores the distribution with sufficient efficiency. ESS statistics confirm this conclusion and indicate that the chains have generated a sample large enough to make a reliable inference. Finally, the graphical representation of the marginal posterior distributions, as well as the values of mean, median and mode suggest that the distribution of the chain values has converged to the target distribution. By using different starting values we rule out the possibility of pseudo-convergence and ensure that the chains have converged on the point of highest density.

6.3.2 Robustness checks

Firstly, we assess the sensitivity of the estimates for the other main variables in the same way it was done for industrial lobbying. The first four models of table 6.8 employ different proxies for environmental lobbying and the quality of institutions in order to evaluate the consistency of the results when different measurements are used.

The first model replaces the proxy $ENGO$ with *ProtectedArea*. *ProtectedArea* is defined as the percentage of territory that is designated as protected area. We postulate that when environmental lobbying is more influential it succeeds in providing protection to a greater territorial area. Like $ENGO$, *ProtectedArea* exhibits a positive and significant relationship with the hazard of ratification. Countries with higher *ProtectedArea* have a higher probability of ratifying environmental agreements. The second proxy for environmental lobbying is $EnvConcern$. $EnvConcern$ is the percentage of the population that reports being concerned about climate change in a survey conducted in 2008 by Tien et al. (2015) on respondents from 119 different countries. The number of respondents in each countries varies between

-0.7225903, 0.3376975, -0.299422, 0.1899845, 0.2431447, 0.5060046, 0.2540413, 0.0199538, -0.0041608, 0.0000641, -5.096715.

Table 6.8: *Robustness checks*

	ProtectedArea		**EnvConcern**		**Institutions2**		**Institutions3**		**Logit**		**Non-parametric**		**No country RE**	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
$ResourceRent$	-0.007	(0.005)	0.003	(0.004)	0.004	(0.004)	0.004	(0.004)	0.005	(0.004)	0.007*	(0.004)	0.005***	(0.002)
$ENGO$					0.024***	(0.006)	0.025***	(0.006)	0.023***	(0.006)	0.021***	(0.006)	0.018***	(0.002)
$EnvConcern$	0.005*	(0.003)												
$ProtectedArea$			0.018***	(0.003)										
$Institutions$	0.305**	(0.174)	0.127**	(0.058)					0.107**	(0.054)	0.061*	(0.046)	0.200***	(0.028)
$Institutions2$					0.223***	(0.050)								
$Institutions3$							0.236***	(0.050)						
$EnvConcern.Instit$	-0.004**	(0.002)												
$ProtectedArea.Instit$			-0.004*	(0.003)										
$ENGO.Institutions$									-0.008**	(0.004)	-0.009**	(0.004)	-0.013***	(0.001)
$ENGO.Institutions2$					-0.010***	(0.004)								
$ENGO.Institutions3$							-0.010***	(0.004)						
$ResourceRent.Instit$	-0.003	(0.004)	0.003	(0.003)					0.003	(0.003)	0.005*	(0.003)	0.003***	(0.002)
$ResourceRent.Instit2$					0.002	(0.003)								
$Resourcerent.Instit3$							0.002	(0.003)						
$logIncome$	0.023	(0.187)	0.232*	(0.164)	0.184	(0.152)	0.213*	(0.152)	0.261*	(0.165)	0.221*	(0.157)	0.353***	(0.091)
$logIncome^2$	0.002	(0.012)	-0.014*	(0.010)	-0.010	(0.010)	-0.010*	(0.010)	-0.015*	(0.010)	-0.010	(0.010)	-0.020***	(0.006)
$FreedomHouseCL$	-0.129***	(0.025)	-0.121***	(0.020)	-0.110***	(0.019)	-0.110***	(0.019)	-0.142***	(0.021)	-0.135***	(0.020)	-0.097***	(0.012)
$ThreatenedSpecies$	1.101**	(0.624)	0.605*	(0.464)	0.536	(0.426)	0.546	(0.435)	0.689*	(0.481)	0.475	(0.441)	0.343***	(0.178)
$logForest$	0.061***	(0.021)	0.056***	(0.015)	0.054***	(0.015)	0.053***	(0.015)	0.061***	(0.016)	0.058***	(0.016)	0.066***	(0.006)
$RatRegion$	0.481***	(0.080)	0.594***	(0.063)	0.635***	(0.063)	0.599***	(0.063)	0.658***	(0.069)	0.764***	(0.070)	0.433***	(0.059)
$RatUS$	-0.689***	(0.082)	-0.717***	(0.069)	-0.600***	(0.070)	-0.710***	(0.069)	-0.770***	(0.074)	-1.065***	(0.073)	-0.738***	(0.067)
$RatChina$	0.379***	(0.070)	0.357***	(0.058)	0.495***	(0.059)	0.360***	(0.058)	0.395***	(0.062)	0.394***	(0.059)	0.357***	(0.058)
$RatRussia$	-0.199	(0.165)	-0.206*	(0.135)	-0.230**	(0.136)	-0.190*	(0.134)	-0.225*	(0.145)	-0.148	(0.133)	-0.286***	(0.129)
$RatIndia$	0.229***	(0.071)	0.252***	(0.058)	0.390***	(0.057)	0.256***	(0.057)	0.273***	(0.062)	0.217***	(0.058)	0.196***	(0.057)
$RatGermany$	0.313***	(0.063)	0.332***	(0.053)	-0.250***	(0.054)	0.327***	(0.052)	0.353***	(0.056)	0.151***	(0.053)	0.256***	(0.052)
$Regional$	0.764***	(0.231)	0.862***	(0.227)	0.819***	(0.237)	0.882***	(0.227)	0.914***	(0.237)	0.697***	(0.242)	0.830***	(0.233)
$FrameworkAgreement$									0.186	(0.225)	0.199	(0.233)		
t	0.059***	(0.012)	0.038***	(0.010)	0.073***	(0.009)	0.041***	(0.010)	0.039***	(0.010)			0.025***	(0.009)
t^2	-0.007***	(0.001)	-0.006***	(0.000)	-0.006***	(0.000)	-0.006***	(0.001)	-0.006***	(0.001)			-0.005***	(0.000)
t^3	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)	0.000***	(0.000)			0.000***	(0.000)
$cons$	-5.501***	(1.070)	-5.670***	(0.846)	-5.280***	(0.791)	-5.420***	(0.794)	-5.985***	(0.878)	-19.418***	(9.331)	-5.937***	(0.465)

Robustness checks (continued)

	ProtectedArea		**EnvConcern**		**Institutions2**		**Institutions3**		**Logit**		**Non-parametric**		**No country RE**	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Random part														
Variance *treaty* level	2.384	-0.288	2.575	-0.302	2.57	-0.302	2.591	(0.304)	2.885	(0.343)	2.978	(0.347)	2.359	(0.278)
Variance *country* level	0.216	-0.036	0.28	-0.036	0.218	-0.028	0.223	(0.029)	0.281	(0.036)	0.243	(0.031)		
Units: *treaty*	254		257		257		257		257		257		257	
Units: *country*	118		189		190		190		190		190		190	
Obs: *ratification*	132756		217848		219266		219266		219266		219266		219266	
DIC:	39814.16		55767.59		56002.29		55975.69		55900.92		40792.95		57746.34	
Burnin:	200000		200000		200000		200000		200000		250000		100000	
Chain Length:	250000		250000		250000		250000		250000		300000		200000	
Thinning:	2		2		2		2		2		2		2	

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

500 and 8000. The assumption behind the use of this variable is that environmental lobbying correlates with the public's concern for the environment. This relationship could be affected by cultural and political factors but, in general, a higher environmental concern should result in stronger environmental pressure. The estimate for *EnvConcern* is positive and statistically significant at the 10% level.

Both *EnvConcern* and *ProtectedArea* indicate that stronger environmental lobbying increases the chances of ratifying environmental agreements. These results are consistent with those of model I.

Table 6.9: *Correlation matrix for proxies in robustness checks*

	1	2	3	4
1. ProtectedArea	1.000			
2. EnvConcern	0.077	1.000		
3. Institutions2	0.164	−0.360	1.000	
4. Institutions3	0.174	−0.352	0.925	1.000
5. Institutions	0.183	−0.335	0.962	0.948
6. logIncome	0.265	−0.262	0.810	0.846
7. FreedomHouseCL	−0.315	0.099	−0.684	−0.727
8. ThreatenedSpecies	−0.166	−0.383	0.217	0.153
9. logForest	0.181	−0.001	−0.099	−0.039

We also experiment with two additional indices for the quality of institutions. *Institutions2* is the "Government Effectiveness indicator" from the World Governance Indicators (World Bank, 2017b) and *Institutions3* is the "Economic Freedom index" by Fraser Institute (2017). These indicators aggregate several aspects of institutional quality into one measure and are consistently calculated for a large number of countries and years. Both indicators are similarly constructed but have been compiled by different organisations. They capture several aspects related to the quality of institutions, including: the efficiency of the bureaucracy, rule of law, protection of property rights, quality of economic legislation and the extent of corruption in business practices. The results for these two variables are positive and strongly significant; countries with high scores in *Institutions2* and *Institutions3* seem to engage more in international cooperation. We obtain this result after controlling for other political and economic factors such as the level of income and the state of democracy. Institutions appear to be a crucial determinant of ratification.

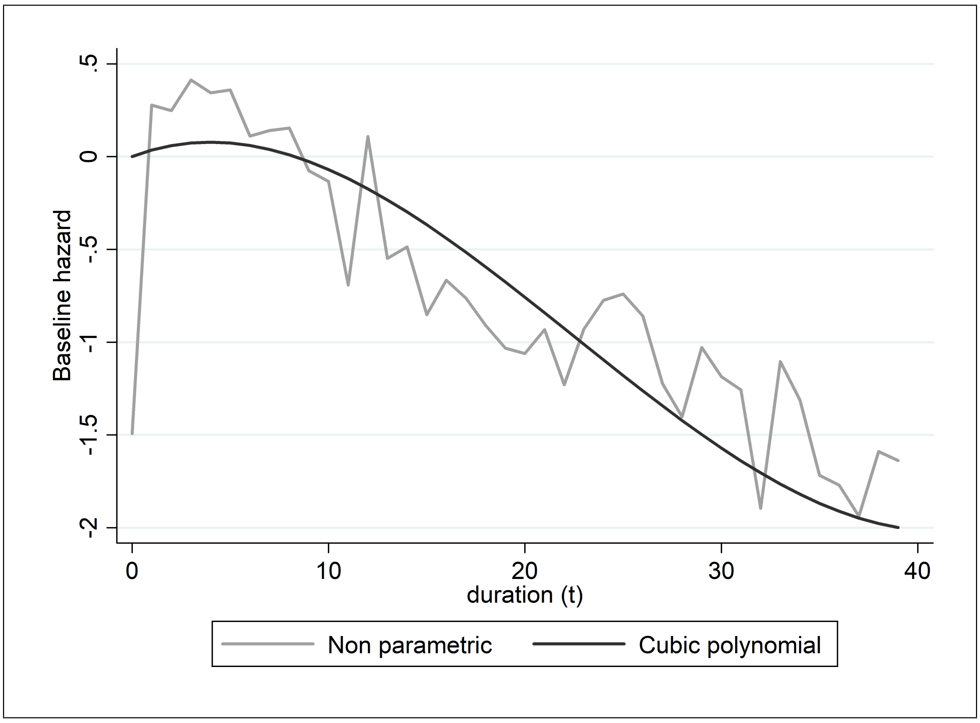

Figure 6.3: *Comparison of the baseline hazard of model I with a non-parametric definition*

Notes: In discrete survival models a way of obtaining non-parametric baseline hazard function is to use dummy variables for each duration interval. Here, we compare the non-parametric definition to the cubic polynomial we use in Model I.

As a further validation of our model, in table 6.8 we report the estimates of the model when a different link function and baseline hazard definition are used. Model *Logit* shows that the estimates obtained with a logit link are essentially identical to the ones obtained with a cloglog link function. The next model is estimated with a non-parametric baseline function instead of a cubic polynomial. In a discrete setting the non-parametric baseline is derived using dummies for the individual duration periods. As a result, this approach implies the estimation of a much larger number of parameters, heavily affecting both the estimation time and convergence speed of the parameter chains. The estimates of the model have all the same sign and are very close to the ones in model I. The only differences are a slightly lower coefficient for $Institutions$ and a slightly higher *ResourceRent*. The increase in *Resourcerent* makes the variable significant at the 10% level of significance. The other estimates do not substantially change from the results in other models. In figure 6.3 we compare the non-parametric baseline hazard with the baseline hazard in model I. The cubic polynomial seems to be a reasonable approximation of the non-parametric version and does not seem to distort the final results. Hence, In model I we opt for the more parsimonious cubic polynomial. The vast gains in estimation time make it a worthwhile simplification and — despite being less versatile than the non-parametric definition — we deem the cubic polynomial is sufficiently accurate.

Finally, in the last column we present the results for a simplified version of model I in which the country random effect is omitted. The estimates are very close to the ones of model I. However, the standard errors are consistently biased downward, leading to erroneous conclusions on the significance of the parameters. This result highlights the importance of using a multilevel strategy to model the clustering of ratifications within the same country and also shows that, despite most of the heterogeneity lies at the treaty level, the country effect needs to be included in the analysis. Our model assumes normality at the treaty and country levels. This property is inspected in Figure 6.4 where the cumulative distribution of the treaty and country residuals are plotted against a cumulative normal distribution. If the residuals were distributed as a perfect normal distribution the plots would lie along the diagonal line. We observe that both the country and the treaty effects follow very closely the diagonal line suggesting that they are approximately normally distributed.

Overall the results are stable and consistent with what is found in section 6.1. The findings are unaffected by changes in the definitions of lobbying and quality of institutions. Different proxies are experimented leading to similar conclusions. We also experiment with different specifications of the model. The results obtained with a non-parametric baseline hazard, a different link function and a different multilevel specification, are all similar to those in Model I.

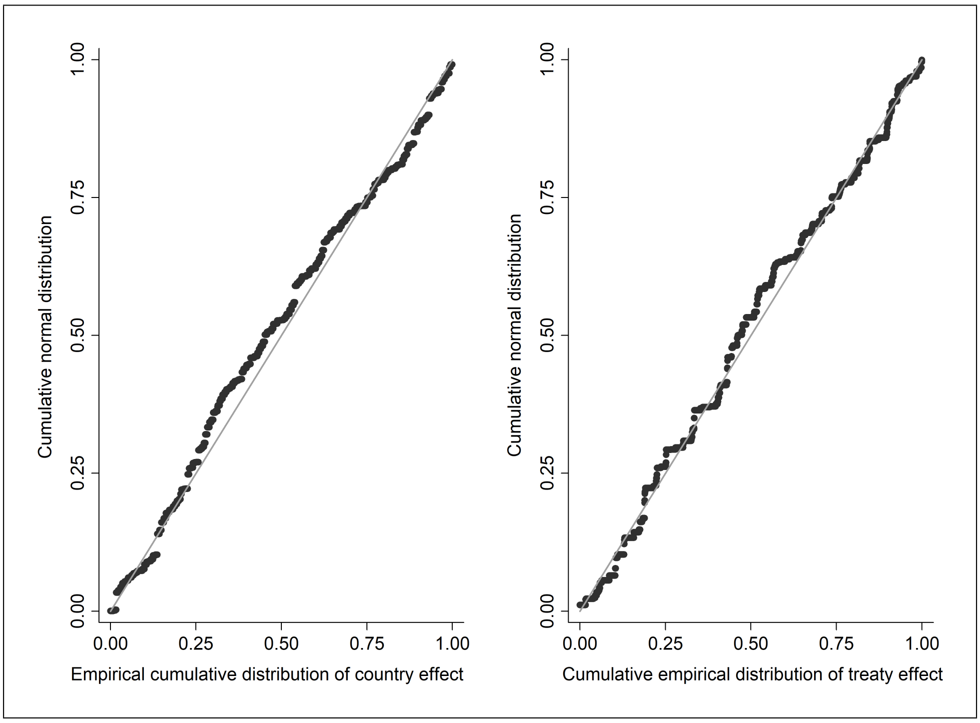

Figure 6.4: *P-P plot for the distribution of the treaty and country effect*

Notes: The empirical distribution of the treaty and country effects are plotted against a cumulative normal distribution to check for normality. Both distributions follow very closely the diagonal line, suggesting normality in both treaty and country random effects.

6.4 Discussion of the results and policy implications

Figure 6.5 provides a good visualisation of model I. 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. A hypothetical average treaty has approximately 45% chances of being eventually ratified. Nevertheless, participation upturn varies widely among treaties. Our model highlights that treaty characteristics are responsible for a much larger share of the heterogeneity in ratification than country factors. 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 there is a large difference between the ratification rate of regional and global agreements. Besides these features, the figure also shows how the probability of ratification evolves over time according to our model. Most ratifications take place in the initial 10 years, after which the probability of joining the treaty significantly declines. After 20 years any additional ratification is very unlikely. This behaviour fits well with the ratification timings observed for most environmental treaties.

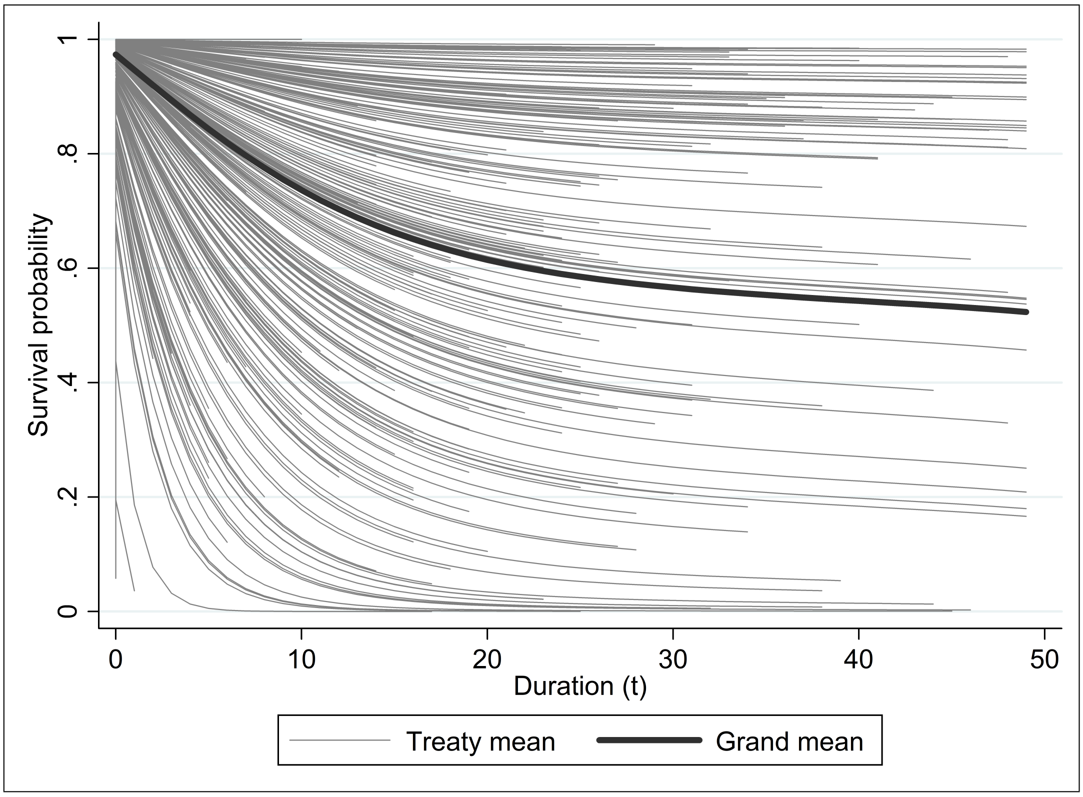

Figure 6.5: *Survival functions for the environmental agreements*

Notes: All survival probabilities are calculated by keeping the country variables at their mean values.

The results of the analysis show that environmental lobbying has a positive effect on the ratification of environmental agreements, while industrial lobbying does not seem to affect the probability of ratification. We put forward an explanation for this result based on the lobbying preferences of environmental and industrial groups. Environmental lobbying target treaties because they see it as a necessary step to legitimise their action and treaties 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, for ENGOs environmental agreements are also the most effective way of addressing large environmental issues. Lobbying on national government could also be part of a coordinated effort to address the problem globally. In fact, 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. Environmental agreement can guarantee this reciprocity. In addition to that, the ratification of environmental agreements is a single legal act; this makes it easier to influence and verify progress compared to other types of regulations which could be more diffuse or capillary. On the other hand, the industrial lobbies target the implementation phase because they are relatively easier to slow down, often draw less attention, and could be easier to influence by local influential groups. In the next chapter, we explore this thesis more in detail by testing the effect of industrial lobbying on several indicators for environmental domestic policies.

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 are consistently impacting 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) and shows that the conclusion holds even on 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 capacity of a country 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 the participation of developing nations. These provisions mitigate the impact that a lower income level might have on the willingness to join the environmental agreement. Secondly, income levels tend to correlate with the quality of institutions and democracy. 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.

A last point can be made on the interactions between nations. Our findings corroborate the results of Bernauer et al. (2010), Perrin & Bernauer (2010), Sauquet (2014) and Yamagata et al. (2017) — among others — on the interdependence among the ratifications of different countries. The 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 baseline hazard of ratification is multiplied by as much as 80%. Furthermore, we find that the action of superpowers and big nations can have a notable effect on other countries. Given the size of countries like China and India, their ratifications have tremendous implications for the success of environmental agreements. We find that when one of these two countries ratify, they notably increase the hazard of ratification of other nations. On the contrary, superpowers like the United States have a polarising effect on foreign countries; the overall effect tends to be negative in terms of number of countries that ratify an agreement. In general, the higher the number of ratifications the higher the probability of success of a treaty. 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 content and implication brought about by each single agreement. This study stresses the importance of securing the participation of influential nations which could play a critical role in the success of the treaty. These nations can have a decisive effect in tilting neighbouring nations toward ratification and triggering a domino effect in ratifications.

The ratification of environmental agreements is also the result of a number of unique factors associated with countries and treaties. In figure 6.6 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 to ratification. Several countries have a significant positive or negative effect associated to unobserved characteristics. 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. For many countries in the middle of the distribution the effect overlaps and only a minor difference can be discerned. The individual unobserved characteristics play an even larger role among treaties. It is interesting to notice how most of the agreements that receive high media coverage tend to have a significantly positive effect beyond the

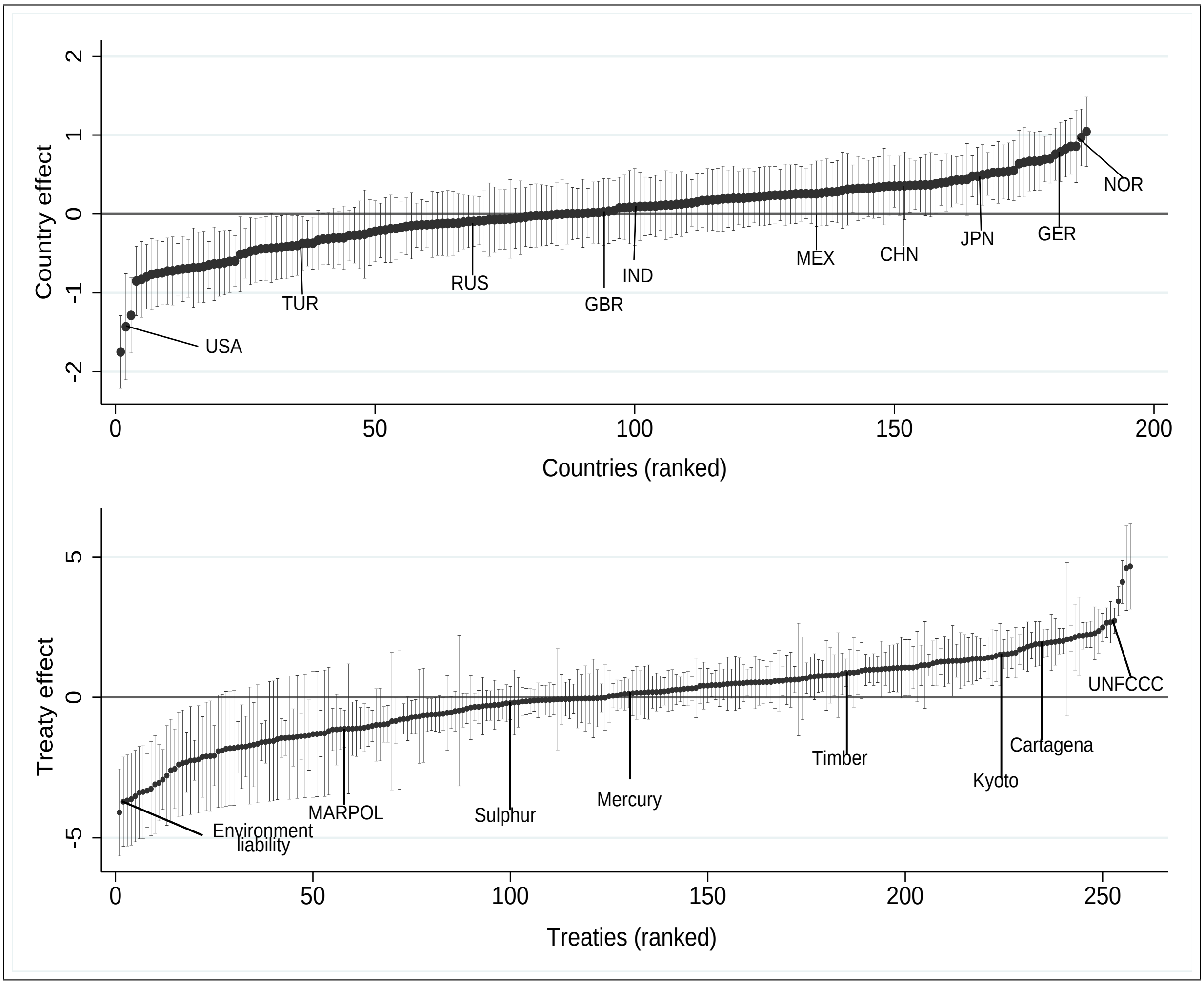

Figure 6.6: *Caterpillar plots for the treaty and country effects*

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).

treaty variables we account for. Even the Kyoto Protocol (1997), a treaty deemed hard to ratify, is located in the right-hand of the distribution. Compared to country effects, the share of treaties having a significant effect is even larger. Many agreements located in 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[5] and, to this date, was not ratified by any of its potential ratifiers. The smaller number of ratifiers and the low variability in the outcome lead to less precise results for the agreement.

In summary, this analysis led to several conclusions regarding the factors motivating the ratification of environmental agreements. The characteristics of countries and their interactions can shape the incentives to ratify and affect the timing of ratification. Nevertheless, the content of an agreement and the manner it is designed exert an even greater impact on ratification choices. For example, we highlight that regional agreements often achieve higher participation rates than global agreements thanks to their easier negotiation. This finding supports the claim of Barrett (1999) and Osmani & Tol (2010), who argue that a more efficient approach to tackle global environmental issues could be to design a set of interrelated regional agreements instead of a monolithic global treaty. With regard to our main research question, we find that environmental lobbying has a positive effect on ratification while no significant effect is found for industrial lobbying. In this section we presented a possible explanation for this result based on the preferences of lobbies. This explanation will be tested in the next chapter. Finally, the quality of institutions plays a very important role in fostering international cooperation on environmental issues. We find that better institutions are consistently associated with a higher probability of ratification and that the effect of environmental lobbying is stronger when the quality of institutions is lower. Two reasons for this are that lobbying practices are generally more effective in corrupt situations and, secondly, countries with better institutions channel environmental demands more effectively through the administrative and political system, hence reducing the need for environmental lobbying on behalf of civil society.

[5]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".

6.5 Application of the results

In this section, we explore some of the applications of this study. Model I can be used to predict and compare ratification probabilities for specific countries. Predictions can help building a concrete understanding of the factors affecting participation in environmental agreements. For example, figure 6.7 is the plot of the hazard of ratification for a typical agreement by Germany, China and India. Germany has the highest probability of ratifying an agreement; the difference is mainly driven by the higher level of income per capita, better institutions and the level of democracy. Besides the comparison between nations, the figure depicts how the hazard of ratification evolves throughout time. The chances of ratifying a treaty are the highest in the first 10 years of existence. Then, they decay and remain stably low; at high durations ratification becomes very unlikely. Simulating probabilities for different countries could help negotiators in the process of drafting agreements. It could help identifying and preparing more effective environmental agreements, capable of securing a widespread participation.

6.5.1 Simulating ratification probabilities of treaties

The model can be used to compare the ratification behaviour of countries, but arguably the best use is to assess the probability of ratification for different treaties. The probabilities of ratification can be estimated by deriving the survival function for the treaty-country combination ij of interest. First, the hazard function is obtained by calculating the fitted values and inverting the cloglog link function.

$$h_{ij}(t) = 1 - \exp[-\exp(\alpha(t) + \boldsymbol{\beta' X_{ij}} + u_i + u_j)] \tag{6.5.1}$$

Where $\alpha(t)$ is the baseline hazard specification; in our case a cubic polynomial. Then, the cumulative hazard function is calculated as:

$$H_{ij}(t) = \int_0^t h_{ij}(t)dt \tag{6.5.2}$$

Allowing to derive the survival function:

$$S_{ij}(t) = \exp[-H_{ij}(t)] \tag{6.5.3}$$

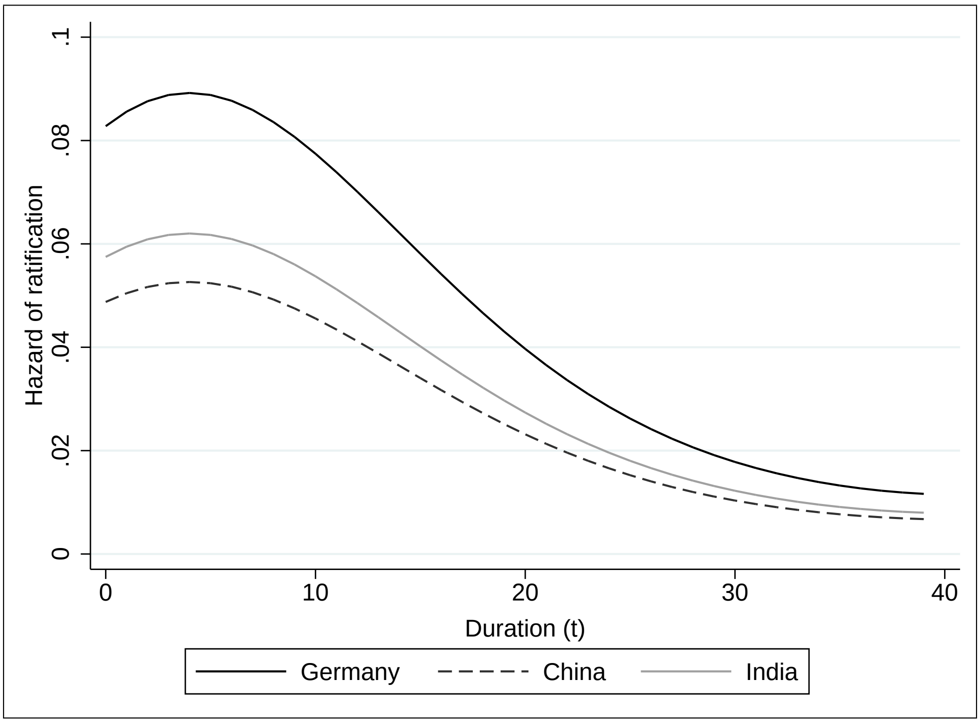

Figure 6.7: *Comparison of the hazard of ratification for three countries*

Notes: All country and treaty variables are kept at their average level.

Finally, a country's probability of ratifying a given agreement by time T is:

$$P_{ij}(T \leq t) = 1 - S_{ij}(t) \tag{6.5.4}$$

In table 6.10 we simulate the probability of ratifying two hypothetical agreements. The first is a *regional protocol* agreement, while the second is a *global framework* agreement. We call "regional" any agreement that, unlike global treaties, is not open to all nations in the world. Regional agreements tend to have a higher ratification rates than global ones: our model estimates that on average regional agreement more than doubles the baseline hazard of ratification. We define a framework agreement as the first treaty on a specific topic; framework agreements usually set the general rules and principles, define the goals and scope of the environmental action and institute governing bodies to the agreement. Sometimes framework agreements impose specific actions and binding obligations, but very often these tend to be incorporated into protocols. We call protocol any agreement that is negotiated under the banner of a framework convention. Protocols are different from amendments in that they create new legal structures and their main purpose is not to modify an existing agreement. Framework agreements usually obtain higher rates of ratification than protocols.

Table 6.10: *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.

We simulate the probabilities of ratifying these two agreements for 5 interesting nations: United Kingdom, United States, Russia, Turkey and Brazil. The two columns for the regional protocol list the probabilities of ratifying the agreement in respectively 5 and 10 years. For the global framework agreement we explore how probabilities change when neighbouring countries ratify the treaty. *RatRegion* is one of the most important factors explaining ratification. To illustrate the interaction among international countries we present a scenario in which all neighbours have ratified and another one in which none has ratified the global framework agreement. The likelihood of ratifying a treaty greatly improves when the neighbouring nations decide to join. We treat as neighbours all countries that are in the same geographic area, as described by the sub-region classification of the UN statistical division (UNSD). In annex A we report how each country is classified geographically. For the global framework agreement we report the probability at $t = 30$; this could be considered as a final ratification probability because after 30 years the hazard of ratification is almost null.

The results of table 6.10 show that among these 5 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 6.6). The results for the global framework agreement demonstrate the effect of the interaction among international ratifications. In some cases the ratification by all neighbours can boost the probability of ratifying by as much as 20 percentage points. This effect alone could greatly contribute to the success of a treaty by triggering a "domino effect" whereby foreign nations are drawn to a treaty by the action of other countries. Last but not least, the examples of table 6.10 show to what extent a regional agreement attracts more ratifications than a global agreement. The ratification probability of the regional protocol after just 10 years is higher than the final ratification probability of the global framework agreement when none of the neighbours ratified.

Besides hypothetical treaties, the model can also be applied to generate predictions on actual agreements. In table 6.11 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 the mining and trading of mercury. It defines a phase-out period, sets standards on storage and disposal of waste and imposes restrictions on the trade in mercury with states that are not members to 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.

In table 6.11, 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 the end of 2018. These predictions seem to be verified by the current ratification status. Up to this point Russia and Turkey have not yet ratified the convention. Nevertheless, it is possible that these two countries might eventually ratify the convention too. By taking a longer time frame, we predict that the probability of ratification in the first 20 years for Russia and Turkey is respectively of 34% and 26%.

In this application, our model is used to give 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 Minamata convention coal reliance is an important aspect behind ratification because coal plants are the second biggest global emitters of mercury

Table 6.11: *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.

(Kessler, 2013). It would also be appropriate to include controls for mercury production and consumption. Our reference model intends to describe the ratification of environmental agreements *in general*, hence it would produce more accurate predictions for specific treaties if expanded with additional information specific to the treaty of interest. Despite all this, the model predicts reasonably well the ratification order among the 5 countries. We can see that countries with higher probabilities are 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 actual probabilities of ratification 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 1 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 impulse of president Obama's administration which concentrated the political weight for such an early ratification (Leenknedt, 2013). Moreover, several clauses of the agreement are very similar to regulations on mercury that had already been domestically introduced in the US, hence lowering the costs linked to the implementation of the treaty (Leenknedt, 2013).

Chapter 7

Further investigating lobbying results: lobbying and domestic policies

7.1 Introduction

Our main models investigate the impact of lobbying and other relevant variables on the ratification of environmental agreements. Despite testing different measures, specifications and interactions, industrial pressure does not seem to be significantly associated with a lower ratification rate. In this chapter, we further investigate this puzzling result to check whether the same conclusion persists at the domestic level. Our analysis evaluates the effects of industrial and environmental lobbying on different areas of domestic policies. We selected 5 dependent variables that capture how the policies of the country fare in environmental terms.

1. $\Delta energymix$ is the share of renewable energy in the electricity production mix of the country. The renewable energy sources taken into account include geothermal, solar, tides, wind, biomass, and biofuels. The data covers a period of 33 years. we take the first difference to avoid spurious results linked to non-stationarity of the data. Data source: International Energy Agency (IEA, 2017).

2. *EnvPolicyScore* is an indicator of the extent to which domestic institutions and policies promote the protection and sustainable use of natural resources and the management of pollution. According to its developers, this index is "intended to capture the quality of a country's policies and institutional arrangements, focusing on key elements that are within the country's control, rather than on outcomes (such as economic growth rates) that are influenced by events beyond the country's control"(International Development Association, 2017). The index is calculated exclusively for low-income countries. The individual scores are attributed by country experts of the World Bank and subsequently reviewed to ensure comparability across countries. The source of the data is the Country Policy and Institutional Assessment (CPIA) database (International Development Association, 2017).

3. *FossilSupport* is the support to fossil fuels in OECD and BRICS countries as percentage of tax revenues. Support is defined as public spending programmes or tax breaks in favour of fossil fuel production or consumption. Data from OECD (2017a).

4. *BiodiversityProtect* is the proportion of sites with significant biodiversity value in the country that is covered by the status of protected area. The data is from the Goal 15.1 of the SDG (UN, 2017). The important areas for biodiversity are identified by the UN Statistical Division (UNSD) by using a subset of the biome composed especially of highly threatened species and birds. Diversity in bird species is often used as marker for general biodiversity because birds are very sensitive to changes in their habitat, the composition of bird population quickly reacts to changes in the environment (Brooks et al., 2001).

5. *EnvInventions* is a variable capturing the relative specialisation in environment related research and technologies. It is calculated by the OECD as the ratio of *i*) the share of environment-related inventions on all inventions (in all technologies) at home over *ii*) the share of environment-related inventions on all inventions (in all technologies) in the world. The number of inventions is estimated from the data on deposited patents. Data from OECD (2017b).

These 5 variables are selected to reflect a broad spectrum of domestic policies. They intend to capture the effort in promoting sustainability, green energy, as well as environmental research and protection. We then use a proxy for industrial pressure to study the impact that lobbying exerts on the environmental outcome of domestic policies. The models we build are used to compare whether the mechanisms that underpin the ratification of treaties operate in the same way during the implementation phase of the environmental commitments. Furthermore, we wish to confirm whether the same conclusions on the role and impact of industrial lobbying are valid also for domestic environmental policies. For each model, two measures of industrial pressure are tested: *ResourceRent* and *ShareIndustry*. *ResourceRent* is the sum of fossil fuel (gas, coal, oil, mineral and forest) rents as a percentage of GDP. Rents are calculated as the difference between the average production cost and the commodity price. Hence, *ResourceRent* captures the extent and relevance of the monopolistic power in the fossil industry. We assume this correlates with lobbying power. *ShareIndustry* is the value added by the industrial sector as a share of the GDP. In the literature *ShareIndustry* is the most common proxy for industrial lobbying.

In the next section we elaborate on the main determinants of each of the 5 policy variables. Then, the subsequent section expounds on the methodological approach and describes the variables of the models. Finally, we present the results of the study and draw important conclusions on the impact that pressure groups have on domestic environmental outcomes.

7.2 A note on the determinants of domestic policies

The impact of interest groups on the formulation and rigour of environmental policies is a fact well established in economic theory. Already Buchanan & Tullock (1975) and Dewees (1983) construct public choice models in which environmental policies are not merely the outcome of a policy maker maximising social welfare; the interests of those that are affected by the policies are also taken into consideration. A more complete formulation of the link between environmental policies and interest groups is produced by Damania (1999) and Fredriksson (1997). Fredriksson (1997) develops a model where competing interest groups contribute to fix the equilibrium tax rate for a pollution tax in which increased strength of the industrial lobby lowers the equilibrium tax rate. Damania (1999) builds a theoretical model of political lobbying to explain the selection of environmental policy instruments. Emission taxes are proposed by parties that represent environmental pressure groups, while industrial lobbies push for less onerous policies such as standards. The intuition behind this model is further developed by Glachant (2008). In Glachant's model the policy maker can choose between 3 environmental policy instruments: emission standard, tax on emission, tradeable emission permits. The author shows that under the influence of pressure groups representing polluting industries, the policy outcome is steered away from social optimum toward the most preferable outcome for lobbying industries.

The relevance of lobbying groups is confirmed by the analysis of Dijkstra (1998) and Beard et al. (2007). The authors of these papers adopt a game theoretical approach to study the selection of policy instruments. Dijkstra (1998) explores the selection between 2 environmental policy instruments (market instruments vs direct regulation) when government decisions are open to the influence of industrial pressure groups. They conclude that market instruments such as tradeable emission caps are implemented less often because of the impact of lobbying activity. A similar conclusion is reached by Beard et al. (2007). They design a two-stage game of political lobbying for policies aimed at improving the quality of the environment. However, unlike previous works, they assume that governments have imperfect monitoring capacities; they can only gather incomplete information on the real quality of the environment. Finally, some initial empirical evidence also seems to strengthen the theoretical link between lobbying and environmental policies. For example, Tanguay et al. (2004) study the determinants of environmental policy stringency in 22 OECD countries. Their findings show that interest groups have sufficient impact to induce changes in environmental regulation.

In this sections we look more in detail at the literature and results surrounding the determinants of our 5 policy variables.

7.2.1 Renewable energy

There is a long-standing body of literature on the relationship between income and energy consumption showing that energy consumption and income are highly correlated (e.g. Kraft & Kraft 1978, Wolde-Rufael 2009). The relationship has mainly been studied along two lines of enquiry: the supply-side and the demand-side. The Supply side looks into the role of energy consumption within the framework of a production function, where energy is considered a factor of production (e.g. Stern 2000). On the other hand, the demand side typically explores the relationship between energy consumption, energy prices, and GDP (e.g. Lee 2005). This approach has also been extended to cover the link of energy consumption with environmental pollution (e.g. Ang 2007). Besides aggregate energy consumption, a number of studies have focused specifically on the use of renewable energy; it is the results of this strand of literature that we will now shortly review.

Sadorsky (2009a) investigates the relationship between income and renewable energy use for a sample of developing nations. The results show that the increase in renewable energy use is mainly driven by the growth in income and the general rise in the demand for energy. In a similar paper, the same author finds that in the long-run, income is positively linked to per capita consumption of renewable energy, while oil price has a negative and small effect on renewable energy use (Sadorsky, 2009b). Gan & Smith (2011) attempt to identify the factors behind differences in the share of renewables in the primary energy for OECD countries. They conclude that income is particularly important, while other factors such as R&D expenditures, energy prices and CO_2 emissions are statistically not significant. The result echoes the finding of another study on OECD countries conducted by Apergis & Payne (2010), which finds that income is significantly linked to the consumption of renewable energy.

The relevance of income and growth is not exclusive to OECD countries; the findings hold for other groups of nations as well. Salim & Rafiq (2012) study the determinants of renewable energy consumption in 6 large developing countries. Again, the level of income is strongly related to the consumption of renewable energy in the long term. In several countries, CO_2 emissions are also found to have an important impact on the adoption of renewable energy sources. The main variables in Salim & Rafiq (2012) model are: income, price of oil and CO_2 emissions. Sineviciene et al. (2017) conclude that the growth rate of GDP and the share of the industry in the economy are key determinants of the consumption of renewable energy in post-communist countries. It is interesting to notice that industrial share — a variable similar to $ShareIndustry$ — has a negative impact on renewable energy, and could be associated with the lobbying practices of industrial interest groups. Finally, Mehrara et al. (2015) study the determinants of renewable energy consumption in a group of central-Asian countries. They employ a very large number of variables in their analysis including the share of industry and several institutional variables. Institutional variables such as indices for political instability, government effectiveness, regulatory quality are all consistently significant across specifications. However, this result could be linked to the lack of a control for the level of income, since only the growth rate of GDP is used.

Both FDI inflows and trade have frequently been linked to an increase in the use of renewable energy, but the evidence is scant. Doytch & Narayan (2015) analyse the relationship between FDI inflows and the consumption of renewable energy, controlling for income and energy prices. The impact of FDI varies substantially according to the sector of destination. The effect on renewable energy tends to be positive mainly for FDI into manufacturing and financial services. With reference to trade, Omri & Nguyen (2014) investigate the determinants of renewable energy consumption on a sample of 64 countries. They find that trade openness is significantly linked to a higher consumption of renewable energy in low-income countries, but not in middle- and high-income nations. They argue that the effectiveness of trade in promoting renewable energy is primarily due to the transfer of technologies. Chen (2018) explores the same research question with data from different provinces in China. The author argues that the volume of trade correlates with the openness of the province. However, the export and import variables are significant only for the provinces of central China.

In addition to the factors we already mentioned, Aguirre & Ibikunle (2014) contend that the "renewable potential" is also important to explain the adoption of sustainable energy sources. They employ estimates on biomass stocks and wind and solar power capacities as proxies for the potential of countries to adopt renewable technologies. Marques et al. (2010) and Mehrara et al. (2015) use the land surface of the country as a rough measure for its renewable potential. Moreover, Marques et al. (2010) and Aguirre & Ibikunle (2014) argue that the energy dependence of the country is a fundamental determinant for the adoption of sustainable energy technologies. Fossil fuel exporters are less prone to consume renewable energy than net energy importers, because of the relative abundance and energy security they enjoy.

Economic growth and oil prices are usually acknowledged to be the pivotal factors influencing renewable energy consumption. On the other hand, trade and CO_2 emissions have a less definite effect and their impact on renewable energy consumption is demonstrated to be heterogeneous across different countries and regions (Marques et al. 2010, Salim & Rafiq 2012, Omri & Nguyen 2014). Other important factors include the energy dependency of the country and their potential for the adoption of renewable energy technologies (Aguirre & Ibikunle, 2014). The share of industry is also considered a potential determinant of renewable energy consumption. A higher share of industry in the economy is often linked to higher energy demand, but also captures the relative strength of industrial pressure groups (Sineviciene et al. 2017). Hence, industrial lobbying is expected to adversely affect the adoption of renewable energy sources.

7.2.2 Fossil subsidies and support

Fossil subsidies and government support to fossil fuel production have been studied less extensively than renewable energy consumption. The major impediment comes from the fact that they are often opaque; the actual dimension of government support is hard to assess and measure (McKitrick, 2017). Hence, a large effort has been invested in estimating the size of fossil subsidies. For example, Jiang & Lin (2014) estimate that fossil subsidies may be worth around 1.65% of Chinese GDP, and Coady et al. (2017) calculate that in 2015 fossil subsidies reached 5.3 trillion USD globally, accounting roughly for 6.5 percent of global GDP. The estimates range widely because of differences in definition and methodology.

Notwithstanding the size of estimates, fossil support and subsidies are deemed to induce a series of undesirable effects. Fossil fuel extraction and production is a polluting activity, emitting large amounts of greenhouse gases and generating harmful side effects on human health and the ecosystems (Pearson, 2011). Subsidies impose a fiscal cost that needs to be covered by any combination of: taxes, debt or lower spending in other areas (McKitrick, 2017). Given the budget constraint of governments, there is an opportunity cost associated with fossil subsidies; what is offered in support of fossil fuel production cannot be invested into more productive activities. Furthermore, the fiscal measures linked with subsidies have a redistributive effect on income, typically away from low-income households, which benefit the least from fossil subsidies (Arze del Granado et al., 2012). According to Coady et al. (2017), subsidies and fossil support measures also discourage investments in renewable energy and improvements in energy efficiency.

Fossil support is linked to several unappealing effects but governments still choose to devote economic resources to fossil subsidies. It is often the case that governments wish to subsidise national production to reduce energy dependency and protect domestic markets from foreign production (Clements et al., 2013). In addition, some scholars have argued that there are political advantages associated to fossil subsidies. According to Overland & Kutschera (2011), governments are willing to subsidise fossil consumption because a reduction in the price of basic commodities, such as electricity or fuel price, is a popular move among incumbent governments. Thus, fossil subsidies confer electoral bonuses in democracies (Overland, 2010) and provide political stability to autocratic regimes (Acemoglu & Robinson, 2001). In countries that export fossil fuels, access to cheap fuel is considered a right, particularly when the state is in control of fossil extraction (Clements et al. 2013, Hartley & Medlock 2008). Overland & Kutschera (2011) give the example of post-Soviet Russia, where fuel prices are expected to be kept low because under the USSR the prices were artificially fixed at a low level.

Overall, there are two sets of factors that appear to be particularly relevant in explaining fossil subsidies. First, it is how extensively a country is economically reliant on fossil fuels for exports or imports (Clements et al., 2013). Secondly, the quality of institutions, in particular, the level of corruption is considered a leading factor in determining the support to fossil fuel (Cheon et al., 2013).

7.2.3 Environmental stringency and environmental protection

Just as subsidies were hard to measure, the stringency of environmental policies is a concept hard to quantify. Environmental policies can fare differently with regards to different environmental goods and the notion of stringency is necessarily nuanced when diverse policies are aggregated (Brunel & Levinson, 2016). Nonetheless, different stringency scores have been developed, such as the one by Botta & Kozluk (2014) and International Development Association (2017). Another common practice is to use pollution abatement costs as an estimate for the stringency of regulation (e.g. Levinson 1996, Becker 2011) or the level of target emissions for specific pollutants (e.g. Cole et al. 2006, Damania et al. 2003). In addition, sophisticated approaches have been proposed to measure performance in specific areas of regulation. For example, Galeotti et al. (2014) propose an approach to evaluate the environmental commitment of a country conditional on the undertaken policies to improve energy efficiency. Besides the measurement of environmental policy stringency, much of the research surrounds the effect of environmental stringency on trade and FDI flows (Cole et al. 2006, Keller & Levinson 2002, Dean et al. 2009, Lu 2010, Grether et al. 2012, Cave & Blomquist 2008). The pollution haven hypothesis underpins this strand of literature, because it implies that states with more lenient environmental regulations have a competitive advantage which, at the margin, should translate into an increase in exports and an influx of capital (Cole, 2004).

The literature highlights the role of income, the quality of institutions, and the pressure of interest groups as the key determinants of the stringency of environmental regulation and environmental protection. Grossman & Krueger (1995), in their seminal contribution, suggest that the relationship between income per capita and environmental quality is non-linear because to higher levels of income correspond a higher demand for environmental protection. As a matter of fact, environment protection and income exhibit a high level of correlation and empirically the evidence shows that economic growth is linked to an increase in environmental policy stringency. Chen (2017), using a system of simultaneous equations, finds that income and the quality of institutions are the two fundamental factors explaining the tightness of environmental regulations. Gallego-Alvarez et al. (2014) study the environmental performance of a large sample of countries. Again, they find that two of the most important factors are income and corruption.

Pellegrini & Gerlagh (2006) and Fredriksson et al. (2005) draw the attention to the special role of democracy and corruption of the institutions. They argue that the protection of the environment is likely to increase with income only when the country possesses good institutions. According to the theoretical model of Fredriksson et al. (2005), democratic participation improves the general quality of environmental regulation. In a second part of his paper this assertion is verified empirically using cross-sectional data on the lead content of gasoline in OECD countries as a proxy for the stringency of environmental regulation. Similarly, Pellegrini & Gerlagh (2006) conclude that low corruption is a major determinant of the stringency of environmental policies However, they find that the relationship with democracy is not as strong as the one postulated by Fredriksson et al. (2005). He et al. (2007) develop a theoretical model in which the stringency of environmental policies is endogenously determined by the presence of interest groups. Their model predicts that in a corrupt setting the quality of environmental regulation is always lower. The conclusions of the model are tested and confirmed with cross-sectional data on the emissions of different pollutants. Industrial lobbying is also considered an important determinant of policy stringency by Galeotti et al. (2014), who suggest that environmental protection is inhibited in countries in which industrial production accounts for a high share of GDP.

7.2.4 Environmental innovation

Environmental innovation is a subject of study in both environmental and innovation economics. Conventionally in innovation economics, the factors affecting firm's environmental innovation are classified as supply- and demand-side. The supply-side stresses the role of technological knowledge in the process of innovation (Lundvall & Johnson, 1994). In fact, the most innovating companies are usually those having significantly larger knowledge capital. Knowledge capital can be accumulated with costly investments in R&D and by hiring skilled employees (Rave et al., 2011). Empirical evidence shows that, at the firm level, technological knowledge and resources invested in R&D are strong determinants of firm's patent production (Mazzanti & Zoboli 2005, Rehfeld et al. 2007, Horbach 2008, Rave et al. 2011). Furthermore, Coe et al. (2009) find that level of education in a country contributes to enhance innovation because it correlates with the qualification of the work force.

Environmental innovation is also explained by demand-side factors. To a large extent, investment in R&D and innovation is undertaken to meet the demand of consumers, companies or institutions. The market-pull factor is critical because innovation is not economically sustainable without a market that rewards technological innovation (Rave et al., 2011). Green et al. (1994) survey a large number of British companies and report that the demand factor is one of the strongest determinants of environmental innovation among companies. In general, the higher the needs or expected benefits for innovation the more advantageous it is to innovate (Horbach, 2008). For this reason, government regulation and incentives play a vital role in stimulating environmental innovation.

In innovation economics, regulation is considered important to overcome the externality deriving from the discrepancy between the private benefit of R&D and the social benefits generated by environmental innovations (Rennings, 2000). On the other hand, environmental economics stresses the role of regulation as a tool to increase the cost of environmental goods and indirectly stimulate environmental innovation. In particular, Porter (1991) and Porter & van der Linde (1995, 1999) claim that research is mostly incremental and may overlook the optimal innovation paths. Thus, government intervention can help steer research efforts toward superior environmental technologies. The work of Porter and van der Linde prompted vast research on the link between environmental regulation and firm performance that goes under the name of the Porter Hypothesis. The controversial Porter Hypothesis states that environmental regulation, despite raising input costs, may stimulate innovation and make companies more competitive (Rave et al., 2011). Jaffe & Palmer (1997) are the first to empirically test this argument. Many other studies followed that considered different measures and aspects of regulation (Blind 2012, Johnstone et al. 2012, Rubashkina et al. 2015 and Franco 2017). Overall, the evidence on the Porther Hypothesis is mixed and no consensus has been reached.

To sum up, both demand- and supply-side factors concur in determining environmental innovation. At the firm level, R&D spending plays an important role in building knowledge capital and ultimately determining innovation (Mazzanti & Zoboli, 2005). The supply side is relevant also at the national level. The empirical analysis of Guloglu et al. (2012) reveals that for G7 countries, the main factors driving innovation are government R&D expenditure, economic growth, and export of high technology products. Similar results are obtained by Bayar (2015); economic growth, financial development and domestic savings are particularly relevant to environmental innovation while FDI is not significant. On the other hand, the demand for innovation is a potent catalyst for environmental innovation (Horbach, 2008) and, through regulation and funding, governments are able to shape private incentives and foster environmental innovation.

7.3 Methodology and variables choice

We select five dependent variables that reflect the sustainability of government's policies. Namely, $\Delta EnergyMix$, $BiodiversityProtect$, $EnvPolicyScore$, $FossilSupport$, and $EnvInventions$. These variables cover diverse areas ranging from environmental research, to the protection of the environment and the use of renewable energy. For every variable a separate model is built in order to capture the effect of industrial and environmental lobbying on specific policy outcomes. We opt for different modelling strategies in order to suit best the distribution and characteristics of the individual dependent variables. In this section we expound on the modelling choices for each variable.

7.3.1 Methodology

$\Delta EnergyMix$ is fitted with a linear specification. We employ Correlated Random Effects (CRE) to tackle the unobserved heterogeneity at the country level. This approach, first proposed by Mundlak (1978) and Chamberlain (1982), works by introducing the country averages of every time-varying variable; the averages are called Mundlak devices. This technique separates the *between* from the *within* effects and yields fixed effect estimates (average marginal effects) for time varying variables. The Mundlak test checks the joint significance of the Mundlak devices. It is a robust version of the Hausmann test (1978), when the Mundlak devices are insignificant the CRE is reduced to a Random Effect estimator. CRE can be extended to unbalanced panels following the approach of Woolridge (2016), who demonstrates that averaging across the unbalanced panels maintains the canonical properties of the CRE. We opt for this approach because of its flexibility and because one of our main variables is time invariant ($ENGO$). In addition to that, year dummies are added to control for time-specific effects. The following model is estimated:

$$Y_{it} = \beta_0 + \boldsymbol{D_t\alpha} + \boldsymbol{X_{it}\beta} + \boldsymbol{\overline{X}_i\gamma} + u_i + \epsilon_{it} \tag{7.3.1}$$

$$u_i \sim \mathcal{N}\big(0,\, \sigma_u^2\big) \qquad \epsilon_{it} \sim \mathcal{N}\big(0,\, \sigma_\epsilon^2\big) \tag{7.3.2}$$

Where Y_{it} is the dependent variable $\Delta EnergyMix$. $\boldsymbol{X_{it}}$ is the vector of independent variables that includes industrial lobbying and other control variables. $\boldsymbol{D_t}$ are year dummies. $\boldsymbol{\beta}$, $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$ are vectors of coefficients while β_0 is a constant. u_i is the country random effect and ϵ_{it} is the error term, both assumed to be independent of each other and to follow a normal distribution. $\boldsymbol{\overline{X}_i}$ is the vector of Mundlak devices, i.e. the country averages for the time-varying variables. The model is estimated with a Random Effect estimator (feasible GLS).

$EnvPolicyScore$, $FossilSupport$ and $EnvInventions$ are fitted with a Poisson model. These variables are left-bounded (non-negative) and heavily skewed with low frequencies for high values and high frequencies for low ones. As seen in figures 7.1 and 7.2, this is particularly evident for $EnvInventions$ and $FossilSupport$. Although Poisson regression was developed for count data (Hausman et al. 1984,Cameron & Trivedi 1986), it is not exclusively restricted to such a type of data (Winklemann, 2008). A direct alternative to Poisson regression would be to use a log transformation of the dependent to account for the left-bound; however, Poisson (GLM) regression is generally superior (Winklemann, 2008). Unlike log-transformed models it can take the

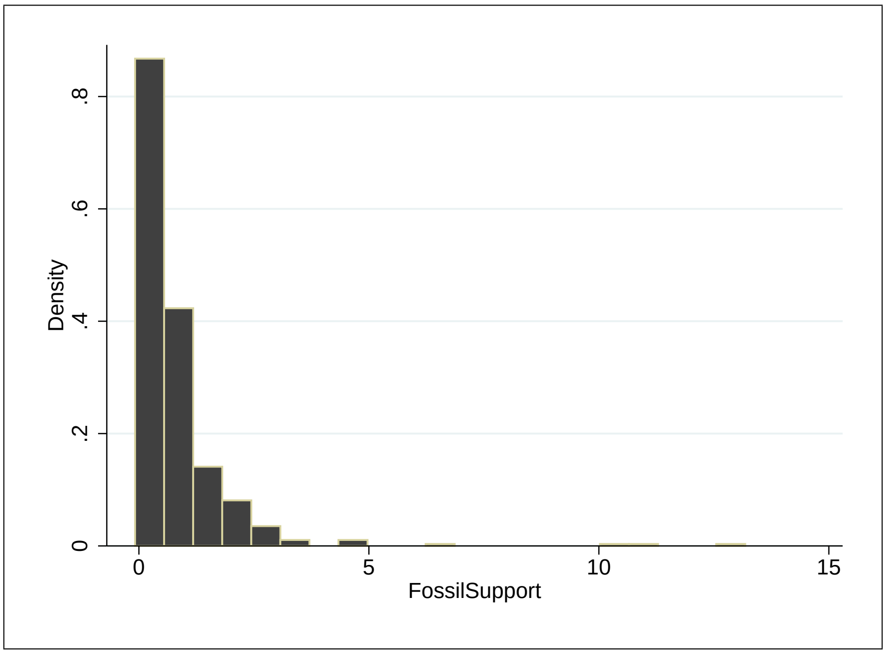

Figure 7.1: *Distribution of FossilSupport*

value of 0, and performs better with values that approach the left-bound (Greene, 1994). As for previous model, we include year dummies and use Correlated Random Effects (CRE). We do not dwell on the issue of overdispertion, since it does not affect the consistency of estimates. The present study is not interested in making probability predictions for domestic policies, so we simply account for overdispertion with robust standard errors.

The Poisson distribution is commonly used to describe the probability of a rare event on the basis of a parameter λ, called incidence rate. Using the same notation of the previous model we can call Y a dependent variable such as $EnvPolivyScore$, $FossilSupport$ or $EnvInventions$. Note that Poisson regressions require positive integers, so we multiply the original $EnvPolivyScore$ by 10 and multiply $FossilSupport$ and $EnvInventions$ by 100. For $EnvInventions$, the values are also rounded to obtain integers. Then, we can define the probability of observing the value y_{it} for country i at time t, conditional on λ as:

$$\Pr\left(Y_{it} = y_{it} \mid \lambda_{it}\right) = \frac{e^{-\lambda_{it}} \lambda_{it}^{y_{it}}}{y_{it}!} \tag{7.3.3}$$

Where the incidence ratio λ_{it} is considered to be determined by a set of regressors.

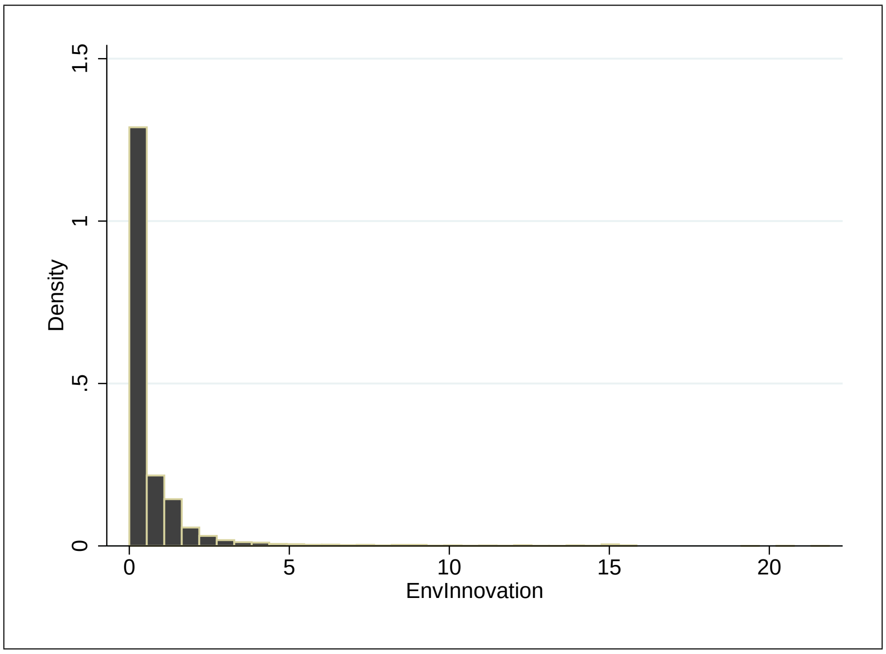

Figure 7.2: *Distribution of EnvInventions*

$$\lambda_{it} = \exp\left(\beta_0 + \boldsymbol{D_t\alpha} + \boldsymbol{X_{it}\beta} + \boldsymbol{\overline{X}_i\gamma} + u_i\right) \tag{7.3.4}$$

$$u_i \sim \mathbf{\Gamma}\left(k, \theta\right) \tag{7.3.5}$$

The notation convention is unchanged from equation 7.3.1. Again, $\boldsymbol{X_{it}}$ designates the vector of independent variables specific to the dependent variable. In this case, the country random effect u_i is assumed to follow a gamma distribution with mean 1 and variance $1/\theta$. The equation is estimated through maximum likelihood with approximation of the log likelihood by adaptive Gauss–Hermite quadrature.

Finally, $BiodiversityProtect$ is strictly bounded between 0 and 100. Hence, a linear model would be ill-suited for this type of data (Papke & Woolridge, 1996). Instead, we treat $BiodiversityProtect$ as a fractional outcome. Following Papke & Wooldridge (2008), we fit a fractional model with a logit link function that we estimate using a Generalised Estimating Equation (GEE). Such a model produces population-averaged effects. Moreover, CRE is implemented by including the averages across the unbalanced panels (Woolridge, 2016). The following model is estimated for $BiodiversityProtect$:

$$\operatorname{logit}\left[E\big(Y_{it}\big)\right] = \log\left(\frac{E\big(Y_{it}\big)}{1 - E\big(Y_{it}\big)}\right) = \beta_0 + \boldsymbol{X_{it}\beta} + \overline{\boldsymbol{X}}_{\boldsymbol{i}}\boldsymbol{\gamma} \qquad (7.3.6)$$

Since some of the series are over 15 years long, the data has an important time series component. This is especially true in the case of $EnergyMix$, which encompasses over 30 years of observations. Thus, we make sure that in all of the models the variables are stationary to avoid spurious results. Stationarity is assessed with the Im, Pesaran and Shin (2003) panel unit-root test, a test that supports unbalanced types of data. Our data is unbalanced because some countries — mainly the nations from the Balkans and Communist bloc — come into existence at a later point in time or dissolve before the end of the observation period. The results of the test are reported in Table 7.2.

7.3.2 Variables selection

Main variables

The results on treaty ratification indicate that stronger industrial lobbying is not associated with lower chances of ratifying environmental agreements. We now wish to establish whether the same results persist at the level of domestic policies. The goal of this analysis is to assess the impact of industrial lobbying on the implementation phase of treaties' environmental commitments. A different model is built for each of the following indicators of domestic policy: $EnergyMix$, $EnvPolicyScore$, $FossilSupport$, $BiodiversityProtect$ and $EnvInventions$. For each of the 5 policy variables we employ two different measures for industrial pressure to verify if lobbying activity is systematically linked to more lenient regulation and scarcer environmental performance. The two indicators for industrial pressure are $ResourceRent$ and $ShareIndustry$.

$ResourceRent$ is the sum of fossil fuel (gas, coal, oil, mineral and forest) rents in percentage of GDP. The rents are calculated as the difference between the average production cost and the commodity price. Hence, $ResourceRent$ captures the extent and relevance of monopolistic power in the fossil industry, which we assume correlates with lobbying potential. $ShareIndustry$ is the value added by the industrial sector as a share of GDP. In the literature, $ShareIndustry$ is the most common proxy for industrial lobbying. Additionally, every model includes $ENGO$ as a proxy for the counterbalancing effect of environmental lobbying. $ENGO$ is measured as the number of environmental

NGOs in the country that are members of the IUCN. In the remaining part of the section we present the control variables of every model. A detailed definition of all the variables can be found in Table 7.1 as well as in appendix C.

Table 7.1: *Definitions and sources*

Variables	Definitions and sources
$\Delta EnergyMix$	Percentage point variation in the electricity production from renewable sources. The energy sources taken into account are geothermal, solar, tides, wind, biomass, and biofuels. International Energy Agency (IEA, 2017).
$EnvPolicyScore$	Score attributed to the sustainability of policies. The score ranges from 1 to 6, with 6 indicating higher levels of importance attributed to sustainability. Country Policy and Institutional Assessment (CPIA) database (International Development Association, 2017).
$FossilSupport$	Government support to fossil fuels (consumption and production) in percentage of tax revenues. "Total fossil support" in OECD Green Growth Indicators dataset (OECD, 2017a).
$BiodiversityProtect$	Proportion of the important sites for biodiversity that are covered by protected area status. Data from the Goal 15.1 of the SDG (UN, 2017).
$EnvInnovation$	Relative advantage in environment-related technologies. A value of 1 indicates that the country develops environmental technologies as much as the average world invention rate. OECD (2017b).
$ENGO$	Number of ENGOs memberships to the International Union for the Conservation of Nature by country in 2017. We assume a constant value over the entire time period. Data from IUCN website.
$ResourceRent$	Sum of fossil fuels rent in percentage of GDP. "Total natural resources rent (%GDP)" in WDI dataset (World Bank, 2017a).
$ShareIndustry$	Share of GDP value added from manufacturing, mining and utilities at current prices. National accounts data (UNSD, 2017).
$FreedomHousePR$	Freedom House index of political rights. On a scale from 1 to 7, where a lower score indicates stronger rights. Freedom House (2017).
$AnnexI$	Dummy that takes the value of 1 if the country is in the Annex I of the UNFCCC (1992).

Definitions and sources (continued)

Variables	Definitions and sources
$\Delta logIncome$	First difference of the logarithm of GDP per capita in current USD. Data from UN National account estimates (UNSD, 2017).
$Export$	Total exports of goods and services, measured as share of GDP. Data from WDI (World Bank, 2017a).
$\Delta logCrudeOil$	Differneced logarithm of the global price of Brent crude oil on the first of January. Original data expressed in Dollars per barrel. Federal Reserve (2017).
$IMFresourcerich$	Dummy variable that takes the value of 1 if the country is on the IMF list of resource rich countries (IMF, 2012). The IMF identifies resource-rich countries mainly on the basis of their reliance on the export of natural resources.
$\Delta ThreatenedSpecies$	Yearly change in the Red List Index; the index indicates the conservation status of species groups in a territory. A higher risk of extinction is associated with lower scores. Data from IUCN website (IUCN, 2017).
$Corruption$	Corruption score from the International Country Risk Guide (Political Risk Service, 2011).
$FossilExports$	Export of fossil fuels, ores and metals over the total value of the merchandise export. Data from WDI (World Bank, 2017a).
$AgricultureReliance$	Value added by agriculture, forestry and fishing as a share of GDP. Data from WDI (World Bank, 2017a).
$EnergyDepletion$	"Energy Depletion" variable from WDI dataset (World Bank, 2017a). Calculated as the "ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years)". The resources taken into consideration are coal, crude oil, and natural gas.
$Land$	Total land surface in thousands squared kilometres. Data from FAO (2017).

Renewable energy development (EnergyMix)

By far the biggest determinants of renewable energy consumption at the country level are demand-side factors such as income, growth and oil prices. We control for the level of income with the dummy $AnnexI$ that takes a value of 1 if the country is in the Annex I of the UNFCCC (1992). Annex I countries are not only the most developed nations, they are also expected to take the biggest action to curb carbon emissions under the UNFCCC (1992) and the Kyoto Protocol (1997). Both these factors could explain consumption patterns in renewable resources. In addition to $AnnexI$, we include the growth in GDP per capita ($\Delta logIncome$) to account for the effect of economic growth.

The demand for renewable energy depends in part on the prices of the competing energy sources. The price of fossil energy is captured by $\Delta logCrudeOil$, the percentage change in the international price of crude oil. An important role in the diffusion of renewable energy has been played by the development of more efficient and affordable renewable technologies. The technological progress is accounted for by including a time trend ($trend$). Moreover, we follow Marques et al. (2010) and Mehrara et al. (2015) by including the land surface of the country ($Land$) as a rough proxy for the "renewable potential". Countries with large territories are more likely to contain exploitable renewable sources of energy. Wind and solar capacities — the two most important renewable technologies — are not strictly related to a country's surfaces but they both require a sizeable land surface to produce significant energy outputs. Smaller nations such as Luxembourg may find it difficult to reach significant levels of production because of the territorial limitations. Moreover, larger land surfaces tend to correlate with richness in environmental resources such as rivers and water basins, coastlines, reliefs, forests or climatic diversity — all factors that generally relate to the possibility of producing renewable energy with alternative renewable technologies.

Finally, a fundamental factor in the weight of renewable resources is the access to fossil energy sources in the country. Hence, a dummy variable ($IMFresourcerich$) is included that takes the value of 1 if the country is on the IMF list of resource rich countries (IMF, 2012). A nation is considered as resource-rich primarily if it exports natural resources or economically depends on the export of natural resources.

Sustainability of domestic policy (EnvPolicyScore)

Similarly to the previous model, we use $\Delta logIncome$ to control for the effect of the growth in per capita income. We do not control for the level of income because the countries in the sample are homogeneous in terms of development, in fact, $EnvPolicyScore$ is calculated exclusively for low income nations[1]. The model also includes $IMFresourcerich$ to account for the fact that countries reliant on natural resources could have different incentives towards environmental policies. In fact, the economic interests probably hinder the implementation of more stringent regulation in countries more dependent on the extraction of natural resources.

The theoretical literature has emphasised the connection between exports and the environmental stringency of policies. According to the pollution haven hypothesis, countries with indulgent environmental regulation have a competitive advantage on the export of pollution-intensive goods (Cole, 2004). Countries reliant on trade are more reluctant to embark in environmental policies (Neumayer, 2002b). We control for this factor by including $Export$ — the relative weight of exports as a share of GDP.

The tightening of environmental regulations often follows a worsening in environmental qualities (Beron et al., 2003). That is to say, a country could be implementing tighter environmental policies because it experiences a strong degradation of the environment. We control for the link with the quality of the environment by including the yearly change in an index on species conservation ($\Delta ThreatenedSpecies$). The conservation of flora and fauna summarises well the overall environmental quality because it is sensitive to most types of pollutions. For example, air, water and soil pollution are all leading factors in species decline. We use the Red List Index (IUCN, 2017) as a reference for our variable because it is reliably estimated for a large number of countries and years.

Lastly, Pellegrini & Gerlagh (2006) and Fredriksson et al. (2005) — among others— have argued that the political institutions of a country play a fundamental part in promoting environmental policies and satisfying the demand for environmental regulation. We use the variable $FreedomHousePR$ to capture the quality of political institutions and political representation. $FreedomHousePR$ is the "Political rights" index computed annually by Freedom House (2017). It ranges from 1 to 7, with lower scores indicating weaker political rights.

[1] The average GDP per capita in 2015 for the sample of countries is 2004 USD ($sd =$ 1939).

Support to fossil energy (FossilSupport)

In addition to the effect of lobbying, which constitutes the focus of the study, we need to control for the strong economic interests linked to fossil subsidies. Clements et al. (2013) suggest that the reliance on the exports of fossil fuels greatly explains governments' support to the fossil sector. When fossil extraction accounts for a large share of the economy, the country may use subsidies to harbour national companies and provide help against foreign competition. Furthermore, it has been argued that producing countries often subsidise fossil energy to keep prices artificially low (Overland & Kutschera, 2011). We use $IMFresourcerich$ and $FossilExports$ to isolate the effect of industrial lobbying from other economic incentives which could bias our main estimates. $FossilExports$ measures the weight of extractive goods in the export basket and is calculated as the share of fossil fuels, ores and metals exports over total merchandise exports. Again, $IMFresourcerich$ is a dummy that takes the values of 1 if the country is considered resource-rich by IMF (2012).

The literature on fossil subsidies highlights the importance of institutions. In particular, corruption seems to be a strong determinant of fossil support (Cheon et al., 2013). We use the Corruption score from the Political Risk Service (2011) to measure the level of corruption in the country. The rating on corruption is compiled under the "International Country Risk Guide", which assesses a large number of institutional elements. Besides corruption, we also control for the democratic credentials of the government with $FreedomHousePR$. Democracy and fossil support could be linked in several ways; political accountability is thought to hinder the support to fossil energy (Cheon et al., 2013) and it has even been argued that subsidies are linked to electoral cycles (Overland 2010, Overland & Kutschera 2011).

To conclude, $AnnexI$ is used to control for the level of income and $\Delta logCrudeOil$ is included to account for any type of relationship existing between market price of fossil products and government support to fossil energy.

Protection of biodiversity (BiodiversityProtect)

The dependent variable is the proportion of important biodiversity sites that are covered by protected area status. It captures the effort that a country invests into environmental protection. We control for the differences in income and development levels with the dummy $AnnexI$, which takes the value of 1 for the Annex I countries of the UNFCCC (1992). This variable isolates the most developed nations that are also expected to engage into more important environmental actions. Furthermore, Pellegrini & Gerlagh (2006) and Fredriksson et al. (2005) stress that the protection of environment strongly improves when a country possesses good institutions and strong democratic participation (Fredriksson et al., 2005), which ensures a stronger accountability of political action. Again, $FreedomHousePR$ is used to measure the democratic quality of the country.

The literature highlights the prominent role of interest groups on the stringency of environmental policy and environmental protection (He et al. 2007, Galeotti et al. 2014). The effect of industrial pressure groups is studied with the variables *ResourceRent* and $ShareIndustry$, while the impact of environmental lobbying is captured by $ENGO$.

The creation of protected areas could also be a response to a trend in the degradation of the environment. Changes in the quality of the environment are proxied by $\Delta ThreatenedSpecies$, which measures the changes in the conservation of species within the country. The conservation of species is an ideal proxy for the quality of the environment because it reacts to virtually all types of human activities. However, the consistency of the estimates could be affected by reverse causality. In fact, the conservation of species could directly respond to the institution of protected areas, with improvements in the quality of the environment following the protection of biodiversity sites. In order to avoid the issues linked to simultaneity, we take the lagged value of $\Delta ThreatenedSpecies$ which cannot be causally determined by the present level of $BiodiversityProtect$. Moreover, the creation of protected areas as a response to a degradation in the environment is likely to occur with a delay in time. Hence, the lagged value of $\Delta ThreatenedSpecies$ is likely to be correlated and causally linked with the present level of $BiodiversityProtect$.

Finally, we control for the size of the country (*Land*) and the share of agriculture, forestry and fishing over the GDP (*AgricultureReliance*). Agriculture, forestry and fishing are all activities that have a direct impact on flora and fauna diversity. They could hamper the protection of wild biodiversity. Furthermore, in countries that are economically reliant on agriculture, forestry and fishing, the incentives for legal protection of biodiversity sites could be curbed. Last but not least, *Land* — the surface of the country in thousand of squared kilometres — accounts for the fact that larger nations are more likely to contain many important biodiversity sites and could behave differently from small nations that only contain few sites.

Environmental research (EnvInventions)

$EnvInventions$ measures the relative specialisation in environmental R&D compared to the rest of the world. Innovation is measured with the number of deposited patents that are related to the environment. Usually, the development of patents is explained by scrutinising company data. The knowledge capital of the firm, investment in R&D, and the market pull are some of the salient determinants of patented innovation at the firm level (Rave et al. 2011, Mazzanti & Zoboli 2005). Whereas at the country level a central role is played by resources and incentives to innovate.

Our main control variables account for the income and institutional differences among nations. The dummy $AnnexI$ is included to control for the level of economic and financial development. In more developed nations companies can rely on better infrastructures. Developed nations are also most likely to be leading the way in term of research and have an accumulated stock of knowledge capital that could facilitate innovation in environmental domains. In addition, we also include $FreedomHousePR$ as a general control for the political and institutional situation of the country.

Guloglu et al. (2012) and Bayar (2015) point out that economic growth is a fundamental determinant of innovation at the country level. Private companies are willing to invest more in research when there is higher economic growth because they anticipate higher returns. $\Delta logIncome$ is the first difference of the logarithm of GDP per capita expressed in current USD. It is approximately equal to the growth rate of GDP per capita.

Several environmental innovations are linked to more efficient use of energy resources. We include the variable $EnergyDepletion$ to control for the demand-side incentives to innovate. $EnergyDepletion$ is the ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years). The resources taken into consideration are coal, crude oil, and natural gas. $EnergyDepletion$ captures the volume of available non-renewable resources weighted on the expected duration of these reserves. Countries that have no reserves, or that are closer to exhausting their reserves, are stimulated to improve energy efficiency and invest into innovation in alternative energy solutions based on renewable technologies.

Table 7.2: Summary statistics

Variables	Obs.	Mean	SD	IPS test
$\Delta EnergyMix$	6859	0.123	1.123	-27.893***
$EnvPolicyScore$	922	3.114	0.555	assumed
$FossilSupport$	449	0.783	1.181	-1.911***
$BiodiversityProtect$	3365	39.700	26.056	-2956.907***
$EnvInnovation$	10450	0.652	1.762	-50.428***
$ENGO$	10838	5.595	8.679	–
$ResourceRent$	7996	7.250	11.149	-12.462***
$ShareIndustry$	8057	23.230	12.895	-7.433***
$FreedomHousePR$	8331	3.770	2.235	assumed
$AnnexI$	10642	0.224	0.417	–
$\Delta logIncome$	7905	0.052	0.139	-47.352***
$Export$	7836	34.874	24.774	-5.453***
$\Delta logCrudeOil$	7308	0.004	0.261	-65.3252***
$IMFresourcerich$	10642	0.324	0.468	–
$\Delta ThreatenedSpecies$	4421	-0.001	0.002	-22.714***
$Corruption$	4822	2.993	1.364	assumed
$FossilExports$	5843	24.919	34.650	-4.481***
$AgricultureReliance$	6312	18.390	15.447	-8.738***
$EnergyDepletion$	6797	2.465	6.726	-12.517***
$Land$	9531	765.401	2118.136	assumed

Notes: The last column reports the W-statistics for the Im, Pesaran and Shin (2003) unit root test. The test null hypothesis is that the individual series have a unit root process. The selection of lags is based on Schwarz Information Criterion. ***, ** and * indicate p-values respectively lower than 0.01, 0.05 and 0.10. "–" designates time-invariant variables while "assumed" indicates the variables that are assumed stationary.

7.4 Results

The results of the Im, Pesaran and Shin (2003) unit root test are reported in Table 7.2. Stationary series are used to avoid spurious results. In the case of $EnvPolicyScore$, $FreedomHousePR$, $Corruption$ and

Land, the results of the test are not reported because the variables are assumed to be stationary. Except for *Land* — which is nearly constant — the other processes assumed to be stationary are discrete scores; typically bounded, they tend to remain stable for long periods of time with occasional step-like shifts. Unit root tests over-identify unit-roots in this type of data, and results are unreliable especially for shorter time series samples. Furthermore, IPS test cannot be performed on the time-invariant series of the panel. Therefore, for *Land* and $FreedomHousePR$ the results are particularly misleading because they ignore the fact that most of the panel exhibits constant scores.

The regression results are summarised in Table 7.3. Poisson models are log-linear, hence the coefficients they yield are usually exponentiated to obtain incidence rate ratios (IRR). We do not follow this practice because we are interested in the direction of the effect more than interpreting the order of magnitude. Also, the output of the other models is not in terms of ratios, so a comparison across the table would be less intuitive. Moreover, for model 7 and 8 we report the marginal effects, hence the absence of coefficients for the constants $cons$. The estimates for Mundlak devices are presented at the bottom of the table.

Our main variables are proxies for industrial lobbying. It would not be very instructive to interpret the magnitude of coefficients as precise effects of lobbying because lobbying is a concept hard to define and quantify. Thus, the scope of the analysis is to understand the relationship between lobbying and environmental policies rather than generating precise predictions. For four out of the five variables, industrial pressure has a significant effect on domestic policies. The only policy variable for which industrial pressure is uninfluential is the protection of biodiversity sites. The protection of biodiversity sites heavily depends on the level of development (proxied by $AnnexI$) but it is also significantly influenced by environmental lobbying. As expected, the reliance on agriculture, fishing and forestry has a negative impact on the protection of biodiversity sites.

According to the results of model 3 and 4, industrial pressure has a general negative impact on the sustainability of the enacted policies, albeit for $ShareIndustry$ the effect is significant only at the 10% level. Environmental lobbying has similar results in the opposite direction: stronger lobbying, proxied by the number of ENGOs, leads to generally more sustainable policies. These results are for a sample of low-income countries and we obtained them after controlling for the level of democracy ($FreedomHousePR$), income growth, the share of exports, the abundance of natural resources ($IMFresourcerich$), and the change in the quality of environment ($\Delta ThreatenedSpecies$). In model 3-6 we

Table 7.3: *Lobbying on domestic policies*

	$\Delta EnergyMix$		$EnvPolicyScore$		$FossilSupport$		$BiodiversityProtect$		$EnvInventions$	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
$ENGO_i$	0.001	0.002	0.005*	0.006**	-0.005	-0.003	0.005**	0.004**	0.008	0.011
	(0.002)	(0.002)	(0.003)	(0.003)	(0.015)	(0.014)	(0.002)	(0.002)	(0.012)	(0.012)
$ResourceRent_{it}$	-0.004***		-0.003**		0.096***		0.001		-0.012***	
	(0.001)		(0.001)		(0.007)		(0.001)		(0.000)	
$ShareIndustry_{it}$		-0.009***		-0.002*		0.019***		-0.001		-0.004***
		(0.003)		(0.001)		(0.004)		(0.001)		(0.000)
$FreedomHousePR_{it}$			-0.019***	-0.018**	0.645***	0.714***	0.002	0.001	-0.059***	-0.058***
			(0.007)	(0.007)	(0.026)	(0.025)	(0.006)	(0.005)	(0.001)	(0.001)
$AnnexI_i$	0.319***	0.318***			0.371	0.179	0.228***	0.189***	0.131	0.200
	(0.065)	(0.062)			(0.601)	(0.635)	(0.049)	(0.051)	(0.217)	(0.221)
$\Delta logIncome_{it}$	-0.132	-0.126	0.022	0.000					0.172***	0.172***
	(0.194)	(0.199)	(0.074)	(0.073)					(0.012)	(0.012)
$Export_{it}$			0.002**	0.002**						
			(0.001)	(0.001)						
$\Delta logCrudeOil_t$	0.856**	0.854**			0.208***	0.243***				
	(0.347)	(0.346)			(0.067)	(0.071)				
$IMFresourcerich_i$	-0.017	-0.041	-0.014	-0.021	0.300	0.247				
	(0.049)	(0.045)	(0.036)	(0.036)	(0.682)	(0.723)				
$\Delta ThreatenedSpecies_{it-1}$			19.034**	17.055*			17.288***	16.932***		
			(8.759)	(8.739)			(4.771)	(4.696)		
$Corruption_{it}$					-0.185***	-0.180***				
					(0.019)	(0.019)				
$FossilExports_{it}$					-0.015***	0.003				
					(0.002)	(0.002)				
$AgricultureReliance_{it}$							-0.004***	-0.005***		
							(0.001)	(0.001)		
$EnergyDepletion_{it}$									0.029***	0.017***
									(0.001)	(0.000)

Lobbying on domestic policies (continued)

	$\Delta EnergyMix$		$EnvPolicyScore$		$FossilSupport$		$BiodiversityProtect$		$EnvInventions$	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
$Land_{it}$	0.019**	0.630					-1.550	-1.844		
	(0.008)	(1.016)					(2.774)	(2.519)		
$trend$	0.018*	0.017*								
	(0.009)	(0.009)								
$cons$	-34.565*	-33.218*	3.486***	3.511***	3.795***	3.273***			3.975***	3.994***
	(18.842)	(18.572)	(0.048)	(0.050)	(0.623)	(0.654)			(0.117)	(0.120)
$ResourceRent_i$							0.004			
							(0.003)			
$ShareIndustry_i$		0.007**						0.006***		
		(0.003)						(0.002)		
$\Delta logIncome_i$		1.784**								
		(0.874)								
$AgricultureReliance_i$							0.006***	0.008***		
							(0.002)	(0.002)		
$FreedomHousePR_i$							-0.017	-0.020		
							(0.015)	(0.015)		
$Land_i$		-0.651					1.524	1.820		
		(1.017)					(2.773)	(2.517)		
$\Delta threatenespecies_i$							0.450	1.820		
							(10.115)	(10.329)		
Observations	4473	4473	822	811	447	447	2635	2619	6241	6247
Countries	138	138	81	80	33	33	177	176	179	180
Years	1982-2015		2006-2015		2000-2014		2000-2015		1972-2014	
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Mundlak test (χ^2)	4.81	8.51**	4.81	6.69	8.42*	9.03*	10.69*	16.10***	2.17	4.71
Model estimator	GLS Linear		GLM Poisson		GLM Poisson		GEE Fractional logit		GLM Poisson	

Notes: ***, ** and * indicate two-tailed p-values respectively lower than 0.01, 0.05 and 0.10. Robust Standard errors are reported in parentheses. For model (7) and (8) the coefficients are marginal effects. For models (3-6) and (9-10) we present the non-transformed coefficients instead of the more common incidence rate ratios (IRR). We are mainly interested in the sign of the coefficients rather than their amplitude; IRR makes comparison with the other models less straightforward.

do not include a control for the level of income because the estimates are for samples of nations in the same income group.

Industrial lobbying, together with the changes in oil price and the richness in natural resources ($IMFresourcerich$), are the main drivers of the variable $\Delta EnergyMix$. In fact, industrial lobbying strongly correlates with increases in the share of fossil sources in the energy production mix. Industrial pressure also leads to a higher government support for the consumption and production of fossil energy (*FossilSupport*) and a reduction in the research and technological innovation related to the environment (*EnvInventions*). With regard to innovation, the results indicate that countries with higher economic growth innovate more in environment related technologies. In addition to that, the depletion, or complete lack, of fossil resources increases the environmental research effort: an increase in *EnergyDepletion* acts as a stimulus for innovation.

Finally, democracy often plays an important role too. More democratic nations, having a lower score on the Freedom House political rights index, tend to implement more sustainable polices, channel less resources into the support of fossil energy and specialise more on environmental innovation. It is likely that the results for democratic states are driven by the larger degree of transparency and accountability over governments' policies.

7.5 Discussion and conclusion

Altogether, the results indicate that industrial pressure bears an effect on domestic policies. Our measures for industrial pressure exhibit a significant impact on 4 out of 5 policy variables. Moreover, the results obtained with *ShareIndustry* are consistent with the ones of *ResourceRent*; the conclusions on the effect of industrial lobbying are preserved. These results contrast with what is observed for the ratification of environmental treaties, where industrial pressure does not seem to be significantly linked to reduced probabilities of ratifying. All this is consistent with the hypothesis that the pressure is exerted during the implementation stage, rather than the ratification stage of the environmental agreements.

Environmental lobbying is linked to a stronger protection of biodiversity sites with the status of protected areas ($BiodiversityProtect$), and it is generally associated with tighter environmental commitments in developing countries ($EnvPolicyScore$). However, environmental lobbying is not found to be a significant factor in promoting environmental innovation, in reducing the support to fossil fuels and it is also not significantly linked to higher shares of renewable energy in the production mix.

The measures employed in our models are rough proxies for the strength of interest groups, nonetheless they suggest that industrial lobbying focuses on specific types of policies, particularly the ones more rewarding in economic terms. On the other hand, environmental lobbying seems to focus on governmental action but struggles to produce an effect on factors related to the economy and industry — such as subsidies to fossil energy or the share of renewables in the energy mix.

These findings are explained by the fact that industrial action is directed toward economic outcomes that are tightly linked to industrial interests. In contrast, environmental pressure groups usually do not possess the same economic means of industrial lobbies. The efforts of environmental groups focus on policy makers because they provide the legitimisation for their action and have the enforcing power to bring the desired change. The action of environmental groups is harder to exert on decentralised organisations and non-unitary agents such as private firms. Hence, putting pressure on political institutions is often the only way to influence economic outcomes. For example, environmental groups may aim at protecting biodiversity by pushing for the status of protected area ($BiodiversityProtect$); this form of legal protection is more effective and affordable than direct interventions. Conversely, industrial lobbies have less incentive to fight the creation of protected areas, whereas they reap an immediate return from lenient environmental regulation ($EnvPolicyScore$) or by lobbying for subsidies (e.g. $FossilSupport$).

Furthermore, the results reveal a dichotomy in the strategy that pressure groups adopt with regards to international environmental agreements. In the previous chapter we discussed how environmental lobbying increases the likelihood of ratifying environmental treaties, while industrial lobbying is not associated with a significant effect on ratification. The results vividly contrast the findings of this chapter which illustrate that industrial lobbying exercises an effect on a large number of domestic environmental policy outcomes. This seems to suggest that industrial lobbies concentrate on the implementation stage of treaties rather than ratification. Their action targets outcomes that are directly related to their economic interests. On the contrary, environmental groups consider the ratification of environmental agreements as an important tool to force governmental action, hence the focus on ratification.

The present analysis contributes to the debate surrounding the effect of pressure groups and highlights the dichotomy of their action at the domestic and international level. The findings suggest that environmental and industrial lobbies have different priorities in their actions, and approach the five policy areas we examined in different ways. The analysis confirms the influence of industrial and environmental lobbies on environmental outcomes and provides evidence of lobbying activity that is in line with the prevalent findings in the literature. The major limitation of this study is common across most studies of lobbying. That is, since it is such an elusive practice, lobbying is hard to quantify and measure. Our measures for industrial lobbying serve as a rough proxy for lobbying potential and cannot be used to make predictions on the size and relative strength of pressure groups. Future research could benefit from more detailed data that qualifies and measures more accurately the phenomenon of lobbying. In addition to the measurement difficulty, the scope of the analysis could be expanded to cover a broader spectrum of environmental policy indicators.

Chapter 8

Conclusion

The introductory chapter of this thesis presented a map reporting the number of ratifications for every country. The map showed that ratifications tend to cluster geographically and that developed countries, in general, ratified a larger number of agreements than developing countries. This suggests that economic factors affect the decision to ratify. In fact, it would seem that ratification is simply a function of average income, but a deeper investigation reveals that many other factors are at play. Figure 8.1 displays a map of the ratification rates across the world, which — unlike the map in the introduction — takes into account the number of agreements a country can potentially ratify. The image is very different, and suggests that income is not the exclusive driver of ratification. Many large developing nations have relatively high ratification rates, while some rich nations (e.g. United States, Switzerland or Austria) have lower rates than expected by the sole level of income. The objective of our work is to build a better understanding of ratification. In the course of the study we analysed in detail the determinants of ratification, focusing on the following research questions:

> Do domestic pressure groups influence the ratification of environmental agreements? And how is this relationship affected by the quality of institutions? Are good institutions facilitating international cooperation?

To answer the research questions we assembled the largest data set on ratification in the literature. We also sought to correct the limitations of previous works, in particular by identifying the potential ratifiers for every treaty in the data set. It is the first time this is done. We then estimated a binary multilevel model for duration data with cross-classified random effects. The multilevel structure emerges from the structure of the data, which is characterised by the correlation between the observations within the same country and same treaty. The model is estimated with MCMC and yields several interesting results on the determinants of ratification. This modelling strategy corrects several shortcomings of the existing empiricical literature. Furthermore, in chapter 7 we complemented our analysis of treaty participation with an investigation of the effects of interest groups on the implementation phase of treaties. We investigated the impact of environmental and industrial lobbying on different types of environmental policies. We now pull together all the elements of the thesis to provide a comprehensive answer to the research questions.

8.1 Discussion of the main results

8.1.1 The role of domestic pressure groups and institutions

The main variables in our analysis are proxies for environmental and industrial lobbying. These variables, together with a measure for the quality of institutions, are used to evaluate the influence of interest groups on ratification choices. In chapter 4 we formulated a series of hypotheses on the effect of lobbying and institutions, which we now confront with our results.

The influence of domestic pressure groups

HYPOTHESIS 1: *The likelihood of ratifying environmental agreements decreases when industrial lobbies are stronger*

In sharp contrast with our hypothesis, we find an insignificant association between industrial lobbying and the reduction in ratification probabilities. We experimented with five different proxies for indus-

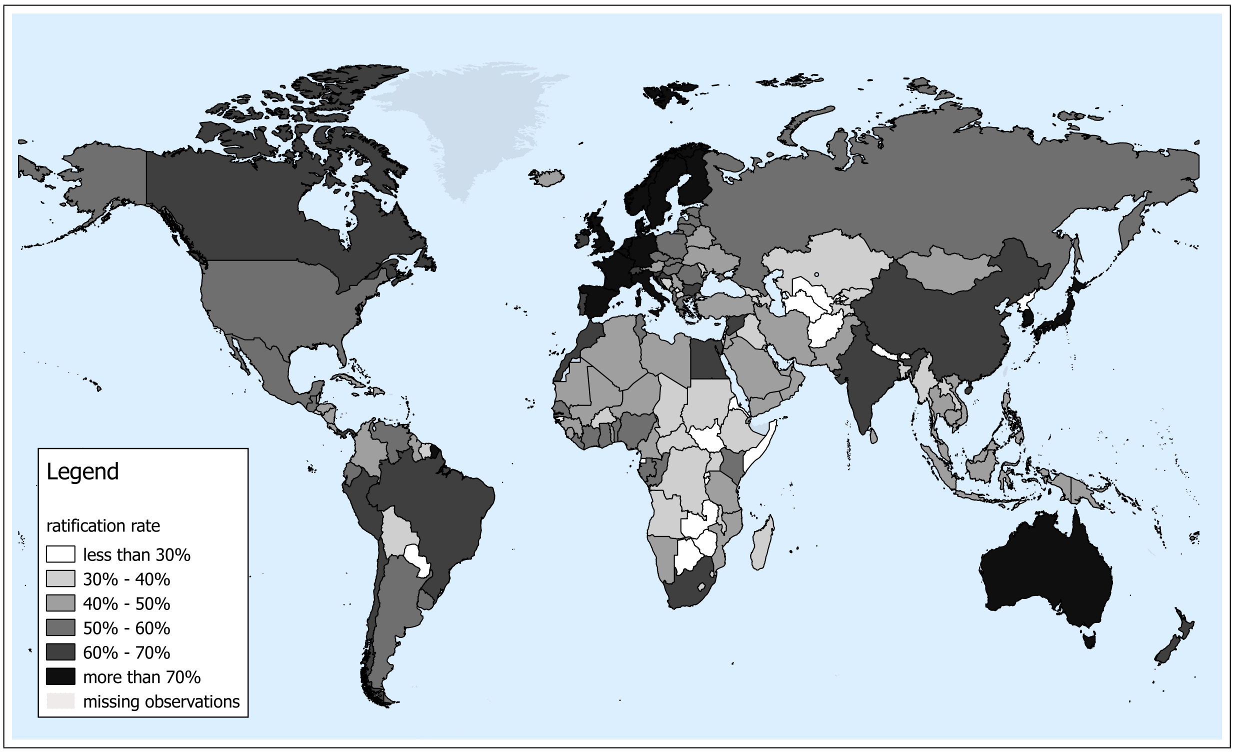

Figure 8.1: *Ratification rates across the world*

Notes: The ratification rate is calculated as the number of ratified treaties in 2017 over the number of treaties the country can potentially ratify. For more information on the ratification data and a detailed explanation of the notion of potential ratifiers, refer to section 5.2.2.

trial lobbying in order to assess the robustness of this finding. The results remain consistent. In contrast with expectations, we do not find a significant effect of industrial lobbying on ratification. A thorough analysis of previous empirical works reveals that the same result was reported in other works which include some proxy for industrial lobbying (Fredriksson & Ujhelyi 2006, Fredriksson et al. 2007, von Stein 2008, Yamagata et al. 2013, Sauquet 2014, Yamagata et al. 2017). Even in widely different models, employing different measurements and different samples, the findings point in the same direction: industrial lobbying is insignificantly linked to lower probabilities of ratifying environmental agreements.

The reason for this counter-intuitive result has never been adequately explored. The explanation we tentatively advance is that stronger industrial lobbying does not translate into lower probabilities of ratification because industrial lobbying practices do not directly target ratification. We suggest that, in general, industrial lobbies prefer to target the implementation phase rather than the ratification of environmental agreements. This hypothesis was tested in chapter 7, where we evaluated the impact of lobbying on different environmental domestic policies. Unfortunately, it is impossible to directly link these domestic policies to specific international environmental agreements. However, we use variables that reflect a broad range of environmental policies to measure the overall national response to environmental commitments. The following five variables are studied: *i*) the change in the share of renewable energy in the energy mix, *ii*) a score on the environmental commitment of the government, *iii*) the economic support provided to fossil sector as percentage of tax revenues, *iv*) the share of important biodiversity sites in the country that have the status of protected area, and *v*) the relative specialisation in environmental research. These five variables are selected to reflect a broad spectrum of domestic policies. They intend to capture the effort invested in promoting sustainability, green energy, as well as environmental research and protection.

The results on domestic policies seem to validate our explanation. For four out of the five variables, industrial pressure has a statistically significant effect on domestic policies. The only policy variable for which industrial pressure is uninfluential is the protection of biodiversity sites. The protection of biodiversity sites heavily depends on the level of income and the strength of environmental lobbying. These results are obtained after controlling for environmental lobbying and other confounding effects. We also account for countries' idiosyncratic factors by using Correlated Random Effects (CRE). Two different proxies for industrial lobbying are used to ensure the results are robust. Our results for domestic policies suggest that industrial lobbying has a negative effect on the quality of environmental policies; this result is consistent across the wide range of policies considered. All of this seems to substantiate our argument that industrial pressure is exerted during the implementation stage of agreements, rather than on ratification.

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

As hypothesised, we find that environmental lobbying has a positive and significant effect on the likelihood of ratifying an agreement. When using the number of Environmental NGOs (ENGOs) as proxy for environmental lobbying, we find that an additional ENGO increases the hazard of ratification by 1.6%, and by 2.1% in correspondence of the average quality of institutions. The effect is significant even when different proxies are used, and it corroborates the results obtained on smaller samples by Fredriksson & Ujhelyi (2006), von Stein (2008) and Bernauer et al. (2013a). Regarding the implementation stage of environmental commitments, we find that environmental lobbying is able to influence specific areas of government regulation, but struggles to impact broader economic variables. In chapter 7, environmental lobbying, together with income, are found to be the two key determinants of the share of biodiversity sites that have protected area status. Furthermore, environmental lobbying seems to improve the general quality of environmental policies enacted by a country. Nevertheless, it fails to influence the other measures of domestic policies, such as environmental research, support to fossil industry, and the share of renewable energy in the energy mix.

The explanation we put forward is based on the lobbying preferences of environmental and industrial groups. Environmental groups target treaties because it is seen as a necessary step to legitimise their actions, and treaties constitute an effective tool to build consensus over environmental issues. Environmental treaties can be used to back the claims of ENGOs and force governments to act on environmental matters. Since transboundary environmental problems involve several countries, for ENGOs environmental agreements are also the most effective way of addressing large environmental issues. Lobbying on national government could also be part of a coordinated effort to address the problem globally. In fact, 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. Environmental agreement can guarantee this reciprocity. In addition to that, the ratification of environmental agreements is a single legal act, which makes it easier to check and verify progress compared to other types of regulations[1]. Conversely, industrial lobbies target the implementation phase because it is relatively easier to slow down, it often draws less attention, and it is possibly easier to influence by local industrial groups. Rather than focusing on governmental regulation, the action of industrial lobbying is directed toward economic outcomes that are tightly linked to industrial interests.

It is harder for environmental groups to influence decentralised organisations and non-unitary agents such as private firms, hence, put-

[1]For example, the compliance with the Kyoto targets is much harder to assess than the ratification of the protocol itself. Implementation often is a diffuse process that entails a large number of measures; hence, it is frequently hard to evaluate the global impact of large governmental policies.

ting pressure on political institutions is often the only way to impact economic outcomes. Our domestic policies results seem to validate this argument: environmental groups protect biodiversity by pushing for the protected area status ($BiodiversityProtect$). For environmental groups, this form of legal protection is generally more effective and affordable than other forms of interventions. The same principle applies to the ratification of environmental agreements because it is a legal act that could be used to force governmental action. Conversely, industrial lobbies have only a scarce interest in disputing the creation of protected areas, while they reap an immediate return from lenient environmental regulation ($EnvPolicyScore$) or by lobbying for subsidies (e.g. $FossilSupport$). The measures employed in our models are crude proxies for the strength of interest groups, but they suggest that industrial lobbying focuses on specific types of policies, particularly the ones more rewarding in economic terms. On the other hand, environmental lobbying seems to focus on governmental action but struggles to produce an effect on factors related to the economy and industry — such as subsidies to fossil energy or the share of renewables in the energy mix.

In many ways, our work corroborates the conclusions of Hagen et al. (2016) who use a game-theoretical approach to show that domestic interest groups may have a strong impact on the size, depth and stability of international coalitions. They find that environmental lobbying is able to positively influence a country's propensity to ratify agreements; while, the effect of industrial lobbying entails lower abatement levels, but has an ambiguous effect on ratification. Our study shows that industrial lobbying indeed does not directly influence ratification. This finding is consistent with the structure of the theoretical models, which postulate that industrial lobbying is exerted during the abatement stage. However, the opposite is found for environmental lobbying. Environmental lobbying appears to focus on the ratification of agreements, but in the existing theoretical literature environmental and industrial lobbies are both assumed to offer contributions to influence abatement levels instead of participation (Haffoudhi 2005, Habla & Winkler 2013, Hagen et al. 2016). There is scope for further research on how conclusions would change if the dichotomy in lobbying strategies were accommodated in theoretical models.

Quality of institutions and interactions with domestic groups

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

Our findings suggest that the quality of institutions plays an important role in fostering participation in environmental agreements. It is estimated that a 1 *s.d.* increase in the quality of institutions leads to an 8% increase in the probability of ratifying environmental agreements. This result is obtained after ruling-out possible effects from correlated variables, such as the level of income and democracy. The quality of institutions also affects the implementation of environmental agreements. In the second part of our empirical analysis we find that countries with better institutions — in particular lower levels of corruption — tend to provide less support and subsidies to the fossil sector. Again, these findings are in line with previous evidence on the quality of institutions (Pellegrini & Gerlagh (2006), Fredriksson et al. 2007, Cheon et al. 2013, Gallego-Alvarez et al. 2014, Seelarbokus 2014).

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

With regards to the interaction with industrial and environmental pressure, we find that indeed the effect of environmental lobbying increases when the quality of institutions is lower. However the interaction with industrial lobbying is insignificant. This conclusion is consistent with the above-mentioned findings for the effect of industrial lobbying on ratification: the quality of institutions does not alter the strategy of industrial lobbies, which still prefer to target the implementation rather than ratification stage. On the contrary, environmental lobbying seems to be more effective in countries with poorer institutions. Two reasons are advanced to explain this relationship. Firstly, in the presence of good institutions, environmental demands are channelled more effectively without the need of pressure from environmental groups. Hence, good quality institutions substitute the effect of environmental groups. A similar conclusion is reached by Bernauer et al. (2013a) on the interaction between environmental lobbying and the quality of democracy. Secondly, lobbying practices tend to be more effective in the presence of corruption. This argument is proposed by Fredriksson et al. (2007) who find that the effectiveness of environmental lobbying on the ratification of the Kyoto Protocol increases with corruption.

Regarding the role played by institutions, our work confirms the theoretical predictions formulated at the beginning of the analysis. Our study also supports previous empirical results on the interaction between lobbying practices and institutional quality (Fredriksson & Ujhelyi 2006, Fredriksson et al. 2007, Bernauer et al. 2013a). In terms of policy recommendations, our findings suggest that measures aimed at improving the quality of institutions — notably by fighting corruption, increasing transparency or bureaucratic efficiency — offer the added benefit of improving a state's capacity to cooperate over environmental issues. Moreover, we conclude that when the quality of institutions is lower, environmental lobbying becomes a more effective tool to apply pressure on ratification choices. This relationship suggests that action by civil society could be used as a vector to improve participation in less developed nations, which are often characterised by comparatively worse quality institutions.

8.1.2 Additional evidence from the study

Income and democracy

In our results, income is positively correlated with ratification of environmental agreements. However, the effect is smaller than anticipated and statistically significant only at the 10% level. Moreover, we find no trace of the supposed non-linearity in the relationship with income (Bernauer et al., 2013a). After accounting for the quality of institutions and democracy, the residual effect of income is relatively weak. We suspect that the impact is mitigated by the differentiated terms often present in environmental agreements. In other words, treaties often include facilitating measures for developing nations that participate in the agreement such as technical assistance, technological transfers or financial aids. According to the principle of *common but differentiated responsibility*, developed nations are expected to take the lead on environmental action and shoulder most of the initial costs of the treaty. This could explain why the level of income does not drastically affect ratification probabilities, especially after we separately account for the quality of institutions and democracy. Both institutions and democracy are found to be important determinants of ratification and strongly correlated with the level of income. Income and democracy have been extensively treated in the ratification literature (e.g. Congleton 1992, Fredriksson & Gaston 2000, Neumayer 2002a, Schulze 2014), however never in conjunction with institutional quality and on a large sample of treaties. The effect of institutional and political variables also extends to the implementation of environmental commitments. For example, we find that democratic nations tend to implement more sustainable polices, channel less resources into the support of fossil energy and specialise more in environmental innovation. It is likely that the results for democratic states are driven by the greater transparency and accountability of governments' policies.

International linkage

Our model allows us to gather evidence on the international interdependence in ratification. We find that a country's choice of ratifying environmental agreements is tightly linked to the ratification of foreign nations. From a theoretical perspective, it is unsurprising that ratifications are interdependent. After all, the benefits and costs of a treaty are inherently associated with the action taken by other nations. Nevertheless, ratifications are not interacting in the way anticipated by game-theoretical models. In game theory the free-ride incentive leads to negative correlation in ratifications, unless a grand coalition is achievable (Marrouch & Chaudhuri, 2015). Instead, we find that if all geographic neighbours ratify the agreement, the hazard of ratification increases by as much as 80%. Our results corroborate previous works on this topic (Perrin & Bernauer 2010, Bernauer et al. 2010, Schulze & Tosun 2013, Schneider & Urpelainen 2013, Yamagata et al. 2013, Sauquet 2014, Davies & Naughton 2014, Wagner 2016, Yamagata et al. 2017), all of which seem to suggest that ratifications are positively related to each other. There is scope for more theoretical research on the reason why free-riding incentives could be overpowered. Empirical contributions often suggest that the result could be due to the linkage of ratification with other forms of cooperation or more simply to reputational gains. Both factors are not traditionally modelled in the theoretical literature.

Moreover, the ratification of key nations can single-handedly boost or hinder participation in environmental agreements. Large nations like China or India increase the likelihood of ratification because they are pivotal for the success of environmental agreements. We estimate that ratification from China increases the hazard of ratification by 43% and India by 29%. In a similar fashion, ratification by European countries also increases ratification probabilities (by 38%), although the estimate is partially pulled up by the strong correlation in the ratifications of the different European states. In contrast, ratifications by the United States and Russia have the opposite effect, leading respectively to a reduction of 51% and 18% in the hazard of ratification. These results could be explained by the polarising effect that Russia and the United States have on the choice of other countries. Despite the fall of the Soviet Union, both countries still have a competing area of influence. The ratification by one of the two countries highly reduces the ratification likelihood by countries in the opposite area of influence, although the effect of Russia's ratification is significant only at the 10% level.

Furthermore, United States' preponderant diplomatic power could impact the terms of the agreements during the negotiation phase, making treaties they ratify less appealing to other nations. All in all, our results bring additional evidence of the strong interdependence in ratifications and reveals the influence of individual big nations on foreign choices. We find that ratifications tend to reinforce each other, with a handful of key nations exerting a particularly strong effect. Our study highlights the importance of securing the ratification of key players, indeed their action alone could potentially kick-start a domino effect.

Treaty characteristics

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

Regionality is the single most important factor explaining ratification rates in our model. On average, the ratification hazard of a regional agreement is 2.37 times greater than the hazard of a global agreement. This shows that agreements can be a very effective tool to solve regional environmental issues because they can easily engage small groups of countries. On the contrary, negotiation of global agreements is more arduous. Finding a compromise for a large number of nations is a complex task and could end up penalising the participation in the agreement or the abatement levels of the agreement (Perman et al., 2003). This is is the first time regional agreements are studied contextually to global treaties. This is made possible by the identification of potential ratifiers in our data set.

Everything considered, the characteristics of the treaty are responsible for the largest share of the variance in ratification. A hypothetical average treaty has approximately 45% chances of being eventually ratified. Nevertheless, participation varies widely among treaties. Our model highlights that treaty characteristics are responsible for a much larger share of the variance than country factors. Differences among treaties are the fundamental cause of disparity in ratification rates. This result is not surprising: the success or failure of a treaty depends chiefly on the content of the treaty itself, and only secondarily on country characteristics or strategical interaction. In addition to that, we also find that, on average, the hazard of ratification peaks around the third year from the opening to ratifications. Thereafter, the treaties become less and less likely to be ratified. Hence, earlier years are fundamental for the success of environmental agreements. The bimodal distribution in ratifications means that treaties tend to end up either with high or low ratification rates. In this context, the credibility of the agreement (according to theoretical literature) and the action of domestic interest groups or foreign countries can play a fundamental role in tilting the balance and triggering ratifications.

8.1.3 Main contributions

This thesis presents a number of innovative aspects and yields important contributions to the literature on environmental agreements. First of all, we assembled a new data set on ratifications. The data regards only agreements strictly related to the environment. This is the largest in the literature and 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 to correct the identification bias and consequential overestimation of survival probabilities in previous works. In the course of our analysis we use a multilevel survival methodology. This allows us to extract a larger amount of information from ratification. In fact, it captures information both on the occurrence and timing of ratifications. Timing is very important in treaties with a high ratification rate because they have low heterogeneity in terms of occurrence. Survival analysis also allows to deal with right-censoring and eliminates the cut-off problem. 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[2].

Our unit of analysis is the country-treaty dyad. We track choices individually and take into account both country and treaty characteristics. This is an improvement over studies that employ ratification counts because a great amount of information is lost in the bundling of treaties or countries (e.g. Recchia 2002, Roberts et al. 2004, Egger et al. 2011, Davies & Naughton 2014). Unlike studies of single treaties (e.g. Fredriksson et al. 2007 or Beron et al. 2003), we pool together a large number of agreements. This strategy permits to generate general inferences on ratification determinants. This approach is powerful, but it introduces a number of challenges: chiefly the treatment of unobserved heterogeneity. Unobserved heterogeneity is an aspect often

[2]A cross-classified multilevel survival model is used also in Leinaweaver (2012). However, the sample of the study is notably smaller, and the results are likely to suffer from major problems relating to the identification of potential ratifiers in regional agreements.

overlooked in previous empirical works. In this regard, we use a multi-level modelling strategy with cross-classified random effects to account for the structure of the data. This modelling approach allows to deal with idiosyncratic factors lying at the treaty and country level. We stress the importance of this approach in modelling treaties because several treaty characteristics are hard to measure and greatly impact the probability of ratification (e.g. stringency of the agreement, cost of participation, preciseness in abatement targets, presence of special clauses, etc.). As highlighted by the theoretical literature, there is a substantial incentive to free-ride on stringent agreements (Wangler et al., 2013). Therefore, it is fundamental to control for unobserved treaty characteristics in order to obtain unbiased estimates.

Moreover, our study is 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 this type of complex models. Other techniques often fail to converge because of the large number of observations, the intrinsic low variability in survival data and the complex structure in random effects. MCMC allows for precise estimates of the complete marginal distributions and, if desired, allows to insert prior knowledge through informative priors. The improved methodological approach, coupled with the larger and more representative data that for the first time tackles the bias introduced by the misidentification of potential ratifiers in less-than-global agreements, consents to generate accurate and general predictions.

Furthermore, we expand the traditional framework of analysis with an analysis of the implementation stage of treaties. In this respect, we study five different variables that capture how a country fares in terms of environmental policies. It is the first time a ratification study is conducted jointly with the analysis of domestic policies. The results on domestic polices are obtained with a methodological approach that controls for unobserved country characteristics. This allows for original and interesting conclusions on the determinants of international co-operation and their final impact on environmental commitments. This framework also led to the identification of a dichotomy in the behaviour of industrial and environmental pressure groups.

Last but not least, we provide an exhaustive review of all the empirical studies produced on the topic of participation in environmental agreements. Our hope is that it can inform a more intense dialogue between the game-theoretical literature on treaty participation and the empirical literature on the determinants of treaty participation. Despite the proximity of these two areas of research, there is a substantial lack of communication between the two.

8.2 Research limitations and future research

Our study develops a framework of analysis that covers both the participation and the implementation phase of treaties. However, it has limitations. First of all, it is hard to establish a direct relationship between agreements and specific environmental policies enacted domestically. Unfortunately, we are unable to study in what ways adherence to a treaty converts into actual implementation; our best attempt (in chapter 7) was to establish a relationship with the general level of environmental commitment. The link between ratification and participation is an element that requires further empirical analysis. Secondly, it would also be interesting to encompass the negotiation phase of treaties. The studying of the negotiation phase could contribute to the understanding of participation and implementation choices. A complete study of the three phases could provide precious insights for the development of more realistic game-theoretical models. Unfortunately, data on the negotiation phase is extremely hard to gather.

With regards to data, 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. Therefore, we relied on proxies to study the relationship between lobbying and ratification. Even though we resorted to the best available measures, some of our proxies have limitations. For example $ENGO$, one of our main measures for environmental lobbying, is constant in time. For this reason we also use alternative time-varying proxies to assess the robustness of our results. Our study was able to establish the sign of lobbying relationships, but the uncertainty over the measurement of variables does not allow us to make exact predictions on the impact of additional “units of lobbying” on ratification outcomes or the environmental commitment of nations. Research would greatly benefit from more complete and accurate data on the activity of interest groups.

Our study is based exclusively on agreements that have taken form. However, in a number of occasions, negotiation of treaties never take place or the countries fail to agree on a treaty. In these cases environmental problems remain unaddressed. Failed cooperation could be investigated in a more general study of cooperation over transboundary environmental issues. This type of analysis could improve our understanding of when and how treaties are negotiated on a given issue between certain countries. Several factors could affect the success of transboundary cooperation: the characteristics of the environmental problem, the magnitude of the problem, the quality of relationships between neighbouring countries, the economic interests linked to the issue, etc..

Lastly, our model assumes that the ratification of a given treaty is independent of the ratification of other treaties. In other words, we ignore the connection that could exist between different environmental agreements in the moment of ratification. 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 one. 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 in the opposite way, that is to say, having complementary ratifications. We believe the assumption of independence is reasonable and better describes the general process of ratification, however there is scope for a deeper inspection of this assumption. Future research could investigate the presence and extent of links between agreements.

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Appendix A

Country information

In the following table we list all the countries for which ratification decisions are tracked in our data set. The time coverage starts in 1950 and ends in 2017. The column "Start" and "End" refer respectively to the dates in which the countries enter and exit the data set. The year is reported only in the case the creation of the country is posterior to 1950 or the country undergoes a dissolution process before the end of the observation period. In a few cases the definitions of the countries have changed during the observation period, but we decided to maintain the nation as a single unit. For example, Germany refers to the German Federal Republic prior to 1991 and to the reunified Germany after 1991. Details on the changes in definitions are provided in the last column of the table. Additional information on on the sample can be found in section 5.2.2.

Table A.1: *Country information*

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Afghanistan			Asia	Southern Asia	
Albania			Europe	Southern Europe	
Algeria	1962		Africa	Northern Africa	

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Andorra			Europe	Southern Europe	
Angola	1975		Africa	Middle Africa	
Antigua and Barbuda	1981		Americas	Caribbean	
Argentina			Americas	South America	
Armenia	1991		Asia	Western Asia	
Australia			Oceania	Australia and New Zealand	
Austria			Europe	Western Europe	
Azerbaijan	1991		Asia	Western Asia	
Bahamas	1973		Americas	Caribbean	
Bahrain	1971		Asia	Western Asia	
Bangladesh	1971		Asia	Southern Asia	
Barbados	1966		Americas	Caribbean	
Belarus	1990		Europe	Eastern Europe	
Belgium			Europe	Western Europe	
Belize	1981		Americas	Central America	
Benin	1960		Africa	Western Africa	Dahomey before 1975
Bhutan			Asia	Southern Asia	
Bolivia			Americas	South America	
Bosnia and Herzegovina	1992		Europe	Southern Europe	
Botswana	1966		Africa	Southern Africa	
Brazil			Americas	South America	
Brunei Darussalam	1984		Asia	South-Eastern Asia	Brunei
Bulgaria			Europe	Eastern Europe	
Burkina Faso	1960		Africa	Western Africa	Upper Volta until 1984
Burundi	1962		Africa	Eastern Africa	
Cambodia	1953		Asia	South-Eastern Asia	Khmer Republic (1970-1975) and Kampuchea (1975-1979)

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Cameroon	1960		Africa	Middle Africa	
Canada			Americas	North America	
Cape Verde	1975		Africa	Western Africa	Cabo Verde
Central African Republic	1960		Africa	Middle Africa	
Chad	1960		Africa	Middle Africa	
Chile			Americas	South America	
China			Asia	Eastern Asia	PRC acquires UN recognition as China in 1971, until 1971 the ROC/Taiwan is recognised as China
Colombia			Americas	South America	
Comoros	1975		Africa	Eastern Africa	
Congo, Democratic Republic of	1960		Africa	Middle Africa	Previously Zaire (1971-1991)
Congo, Republic of the	1960		Africa	Middle Africa	Congo-Brazeville
Costa Rica			Americas	Central America	
Cote d'Ivoire	1960		Africa	Western Africa	Ivory Coast
Croatia	1991		Europe	Southern Europe	
Cuba			Americas	Caribbean	
Cyprus	1960		Asia	Western Asia	
Czech Republic	1993		Europe	Eastern Europe	Czechia
Czechoslovakia		1993	Europe	Eastern Europe	
Denmark			Europe	Northern Europe	
Djibouti	1977		Africa	Eastern Africa	
Dominica	1978		Americas	Caribbean	
Dominican Republic			Americas	Caribbean	
Ecuador			Americas	South America	
Egypt	1953		Africa	Northern Africa	
El Salvador			Americas	Central America	

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Equatorial Guinea	1968		Africa	Middle Africa	
Eritrea	1993		Africa	Eastern Africa	
Estonia	1991		Europe	Northern Europe	
Ethiopia			Africa	Eastern Africa	
Fiji	1970		Oceania	Melanesia	
Finland			Europe	Northern Europe	
France			Europe	Western Europe	
Gabon	1960		Africa	Middle Africa	
Gambia	1965		Africa	Western Africa	
Germany			Europe	Western Europe	Until 1991 West Germany or German Federal Republic
Georgia	1991		Asia	Western Asia	
Ghana	1957		Africa	Western Africa	
Greece			Europe	Southern Europe	
Grenada	1974		Americas	Caribbean	
Guatemala			Americas	Central America	
Guinea	1958		Africa	Western Africa	
Guinea-Bissau	1973		Africa	Western Africa	
Guyana	1966		Americas	South America	
Haiti			Americas	Caribbean	
Holy See			Europe	Southern Europe	
Honduras			Americas	Central America	
Hungary			Europe	Eastern Europe	
Iceland			Europe	Northern Europe	
India			Asia	Southern Asia	
Indonesia			Asia	South-Eastern Asia	
Iran			Asia	Southern Asia	

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Iraq			Asia	Western Asia	
Ireland			Europe	Northern Europe	
Israel			Asia	Western Asia	
Italy			Europe	Southern Europe	
Jamaica	1962		Americas	Caribbean	
Japan			Asia	Eastern Asia	
Jordan			Asia	Western Asia	
Kazakhstan	1991		Asia	Central Asia	
Kenya	1963		Africa	Eastern Africa	
Kiribati	1979		Oceania	Micronesia	
Korea, Democratic People's Republic			Asia	Eastern Asia	Also known as North Korea
Korea, Republic of			Asia	Eastern Asia	Also known as South Korea
Kosovo	2008		Europe	Southern Europe	
Kuwait	1961		Asia	Western Asia	
Kyrgyzstan	1991		Asia	Central Asia	
Laos	1953		Asia	South-Eastern Asia	Lao People's Democratic Republic
Latvia	1990		Europe	Northern Europe	
Lebanon			Asia	Western Asia	
Lesotho	1966		Africa	Southern Africa	
Liberia			Africa	Western Africa	
Libya	1951		Africa	Northern Africa	
Liechtenstein			Europe	Western Europe	
Lithuania	1990		Europe	Northern Europe	
Luxembourg			Europe	Western Europe	

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Macedonia	1991		Europe	Southern Europe	FYROM (Former Yougoslavian Republic of Macedonia), North Macedonia since 2019
Madagascar	1960		Africa	Eastern Africa	Previously Malagasy republic until 1975
Malawi	1964		Africa	Eastern Africa	
Malaysia	1957		Asia	South-Eastern Asia	Formerly Malaya until 1963
Maldives	1965		Asia	Southern Asia	
Mali	1960		Africa	Western Africa	
Malta	1964		Europe	Southern Europe	
Marshall Islands	1986		Oceania	Micronesia	
Mauritania	1960		Africa	Western Africa	
Mauritius	1968		Africa	Eastern Africa	
Mexico			Americas	Central America	
Micronesia	1986		Oceania	Micronesia	
Moldova	1991		Europe	Eastern Europe	
Monaco			Europe	Western Europe	
Mongolia			Asia	Eastern Asia	
Montenegro	2006		Europe	Southern Europe	
Morocco	1956		Africa	Northern Africa	
Mozambique	1975		Africa	Eastern Africa	
Myanmar			Asia	South-Eastern Asia	Burma until 1989
Namibia	1990		Africa	Southern Africa	
Nauru	1968		Oceania	Micronesia	
Nepal			Asia	Southern Asia	
Netherlands			Europe	Western Europe	
New Zealand			Oceania	Australia and New Zealand	

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Nicaragua			Americas	Central America	
Niger	1960		Africa	Western Africa	
Nigeria	1960		Africa	Western Africa	
Norway			Europe	Northern Europe	
Oman			Asia	Western Asia	Muscat and Oman
Pakistan			Asia	Southern Asia	
Palau	1994		Oceania	Micronesia	
Panama			Americas	Central America	
Papua New Guinea	1975		Oceania	Melanesia	
Paraguay			Americas	South America	
Peru			Americas	South America	
Philippines			Asia	South-Eastern Asia	
Poland			Europe	Eastern Europe	
Portugal			Europe	Southern Europe	
Qatar	1971		Asia	Western Asia	
Romania			Europe	Eastern Europe	
Russian Federation	1991		Europe	Eastern Europe	Russia
Rwanda	1962		Africa	Eastern Africa	
Saint Kitts and Nevis	1983		Americas	Caribbean	
Saint Lucia	1979		Americas	Caribbean	
Saint Vincent and the Grenadines	1979		Americas	Caribbean	
Samoa	1962		Oceania	Polynesia	
San Marino			Europe	Southern Europe	
Sao Tome and Principe	1975		Africa	Middle Africa	São Tome e Principe
Saudi Arabia			Asia	Western Asia	
Senegal	1960		Africa	Western Africa	

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Serbia	1992		Europe	Southern Europe	Federal Republic of Yugoslavia until 2003 and Serbia and Montenegro until 2006
Seychelles	1976		Africa	Eastern Africa	
Sierra Leone	1961		Africa	Western Africa	
Singapore	1965		Asia	South-Eastern Asia	
Slovakia	1993		Europe	Eastern Europe	
Slovenia	1991		Europe	Southern Europe	
Solomon Islands	1978		Oceania	Melanesia	
Somalia	1960		Africa	Eastern Africa	
South Africa			Africa	Southern Africa	
South Sudan	2011		Africa	Eastern Africa	
Spain			Europe	Southern Europe	
Sri Lanka			Asia	Southern Asia	Ceylon before 1972
Sudan	1956		Africa	Northern Africa	
Suriname	1975		Americas	South America	
Swaziland	1968		Africa	Southern Africa	
Sweden			Europe	Northern Europe	
Switzerland			Europe	Western Europe	
Syria			Asia	Western Asia	From 1958 to 1961 united with Egypt in the United Arab Republic
Tajikistan	1991		Asia	Central Asia	
Tanzania	1961		Africa	Eastern Africa	Known as Tanganyika until 1964, when it merges with Zanzibar (1963-64)

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Thailand			Asia	South-Eastern Asia	
Timor-Leste	2002		Asia	South-Eastern Asia	
Togo	1960		Africa	Western Africa	Also Togolese Republic
Tonga	1970		Oceania	Polynesia	
Trinidad and Tobago	1962		Americas	Caribbean	
Tunisia	1956		Africa	Northern Africa	
Turkey			Asia	Western Asia	
Turkmenistan	1991		Asia	Central Asia	
Tuvalu	1978		Oceania	Polynesia	
Uganda	1982		Africa	Eastern Africa	
Ukraine	1991		Europe	Eastern Europe	
United Arab Emirates	1971		Asia	Western Asia	
United Kingdom			Europe	Northern Europe	
United States			Americas	North America	
Uruguay			Americas	South America	
USSR		1991	Europe	Eastern Europe	Soviet Union
Uzbekistan	1991		Asia	Central Asia	
Vanuatu	1980		Oceania	Melanesia	
Venezuela			Americas	South America	
Viet Nam			Asia	South-Eastern Asia	Also known as Vietnam. North Vietnam or Democratic Republic of Vietnam until 1976
Yemen			Asia	Western Asia	North Yemen or Yemen Arab Republic until 1990
Yugoslavia		1992	Europe	Southern Europe	
Zambia	1964		Africa	Eastern Africa	

Country information (continued)

Country	Start	End	Region	Sub-Region as defined by UNSD	Notes and alternative denominations
Zimbabwe	1980		Africa	Eastern Africa	

Appendix B

Treaty information

The following table details the complete sample of treaties included in our data set. For every treaty we report the signature year, the secretariat of reference, as well as some identifiers for the subject and the group of treaties (lineage) to which the agreement belongs. Most of the data derives from Mitchell (2017). The number of ratifiers corresponds to the number of distinct entities that deposited a ratification or accession document to the treaty. In some cases the count includes supranational bodies — such as the EU — or states that do not posses full sovereignty — e.g. Maldives, American Samoa or French Polynesia. Information on the number of ratifiers was gathered in 2017; the current number of ratifiers may have changed. The last column takes the value of 0 if it is a global agreement, that is to say a treaty potentially open for ratification to any nation in the world. It takes the value of 1 if the agreement is "less-than-global", i.e. regional agreement. The coding criteria for determining regionality are discussed in section 5.2.2.

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional

Table B.1: *Treaty information*

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Third ACP-EEC Convention	ACP-EEC	General Secretariat of the African, Caribbean and Pacific Group of States	Energy, Habitat, Land, Nature	1984	77	1
Fourth ACP-EEC Convention	ACP-EEC	General Secretariat of the African, Caribbean and Pacific Group of States	Nature	1989	80	1
Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa	African Hazardous Wastes	African Union (formerly Organisation of African Unity)	Africa, boundary, hazardous waste, waste	1991	25	1
African Convention on the Conservation of Nature and Natural Resources	African Nature	African Union (formerly Organisation of African Unity)	Africa, conservation, conservation of nature, natural resources	1968	31	1
African Convention on the Conservation of Nature and Natural Resources (Revised)	African Nature	African Union (formerly Organisation of African Unity)	Africa, conservation, conservation of nature, natural resources	2003	13	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention Concerning the Protection of the Alps	Alps	Permanent Secretariat for the Alps Convention	Habitat	1991	9	1
Protocol for the Implementation of the Alpine Convention Concerning Town and Country Planning and Sustainable Development, Protocol for the Implementation of the Alpine Convention Concerning Nature Protection and Landscape Conservation, Protocol for the Implementation of the Alpine Convention Concerning Mountain Agriculture	Alps	Permanent Secretariat for the Alps Convention	Habitat, Nature	1994	7	1
Protocol for the Implementation of the Alpine Convention Concerning Mountain Forests	Alps	Permanent Secretariat for the Alps Convention	Habitat, Species, Flora	1996	8	1
Protocol for the Implementation of the Alpine Convention Concerning Tourism	Alps	Permanent Secretariat for the Alps Convention	Habitat	1998	8	1
Protocol for the Implementation of the Alpine Convention Concerning the Protection of Soils	Alps	Permanent Secretariat for the Alps Convention	Habitat, Land	1998	6	1
Treaty for Amazonian Cooperation	Amazon Cooperation	Amazon Cooperation Treaty Organisation	Habitat	1978	8	1
Protocol of Amendment to the Treaty for Amazonian Cooperation	Amazon Cooperation	Amazon Cooperation Treaty Organisation	Habitat	1998	8	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Antarctic Treaty	Antarctic	Antarctic Treaty Secretariat	Habitat	1959	56	0
Convention for the Conservation of Antarctic Seals	Antarctic	Antarctic Treaty Secretariat	Habitat, Nature, Species, Fauna, Mammals, Marine, Fish	1972	16	0
Convention on the Conservation of Antarctic Marine Living Resources	Antarctic	Commission for the Conservation of Antarctic Marine Living Resources	Habitat, Nature, Species, Fauna, Fish, Ocean	1980	37	0
Convention on the Regulation of Antarctic Mineral Resource Activities	Antarctic	Antarctic Treaty Secretariat	Habitat, Environment, Nature	1988	0	0
Protocol on Environmental Protection to the Antarctic Treaty	Antarctic	Antarctic Treaty Secretariat	Habitat, Nature	1991	35	0
Annex V to the Protocol on Environmental Protection to the Antarctic Treaty (area protection and management) - Acceptance of Annex V	Antarctic	Antarctic Treaty Secretariat	Habitat, Nature	1991	17	0
Annex VI to the Protocol on Environmental Protection to the Antarctic Treaty (liability arising from environmental emergencies)	Antarctic	Antarctic Treaty Secretariat	Habitat, Nature	2005	13	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement on Cooperation in the Field of Joint Water Resources Management and Conservation of Interstate Sources	Aral Sea	Interstate Commission for Water Coordination	Freshwater, Nature	1992	5	1
Agreement on Joint Activities in Addressing the Aral Sea and the Zone Around the Sea Crisis, Improving the Environment, and Ensuring the Social and Economic Development of the Aral Sea Region	Aral Sea	International Fund for Saving the Aral Sea	Freshwater, Nature, Ocean	1993	5	1
Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic	Arctic Environmental Protection Strategy	Arctic Council	Pollution, Ocean, Oil	2013	8	1
ASEAN Agreement on the Conservation of Nature and Natural Resources	ASEAN	Association of South-East Asian Countries (ASEAN) Secretariat	Nature	1985	6	1
ASEAN Agreement on Transboundary Haze Pollution	ASEAN	Association of South-East Asian Countries (ASEAN) Secretariat	Pollution, Territory	2002	10	1
Agreement on the Establishment of the ASEAN Centre for Biodiversity	ASEAN	ASEAN Regional Centre for Biodiversity Conservation!	Species	2005	9	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement Between the Governments of the Member States of the Association of Southeast Asian Nations and the Republic of Korea on Forest Cooperation	ASEAN	Association of South-East Asian Countries (ASEAN) Secretariat	Habitat, Nature	2011	9	1
Convention Establishing the Sustainable Tourism Zone of the Caribbean	Association of Caribbean States	Association of Caribbean States	Nature, Region	2001	17	1
Protocol to the Convention Establishing the Sustainable Tourism Zone of the Caribbean	Association of Caribbean States	Association of Caribbean States	Nature, Region	2004	5	1
International Convention for the Conservation of Atlantic Tunas	Atlantic Tuna	International Commission for the Conservation of Atlantic Tunas	Nature, Species, Fauna, Fish, Ocean	1966	59	0
Protocol Amending the International Convention for the Conservation of Atlantic Tunas	Atlantic Tuna	International Commission for the Conservation of Atlantic Tunas	Nature, Species, Fauna, Fish, Ocean	1984	33	0
Protocol Amending the International Convention for the Conservation of Atlantic Tunas	Atlantic Tuna	International Commission for the Conservation of Atlantic Tunas	Nature, Species, Fauna, Fish, Ocean	1992	50	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention on Fishing and Conservation of the Living Resources in the Baltic Sea and the Belts	Baltic Sea Fishing	International Baltic Sea Fishery Commission	Nature, Species, Fauna, Fish, Ocean, Region	1973	11	1
Convention on the Protection of the Marine Environment of the Baltic Sea Area	Baltic Sea Marine Environment	Helsinki Commission	Nature, Ocean, Region	1974	11	1
Convention on the Protection of the Marine Environment of the Baltic Sea Area	Baltic Sea Marine Environment	Helsinki Commission	Nature, Ocean, Region	1992	10	1
Convention on Biological Diversity	Biological Diversity	Secretariat for the Convention on Biological Diversity	Species	1992	195	0
Cartagena Protocol on Biosafety to the Convention on Biological Diversity	Biological Diversity	Secretariat for the Convention on Biological Diversity	Species	2000	170	0
Nagoya-Kuala Lumpur Supplementary Protocol on Liability and Redress to the Cartagena Protocol on Biosafety to the Convention on Biological Diversity	Biological Diversity	Secretariat for the Convention on Biological Diversity	Species	2010	37	0
Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation to the Convention on Biological Diversity	Biological Diversity	Secretariat for the Convention on Biological Diversity	Species	2010	84	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention on the Protection of the Black Sea Against Pollution Harmful Substances in Emergency Situations, Protocol on Cooperation in Combating Pollution of the Black Sea Marine Environment by Oil and Other, Protocol on the Protection of the Black Sea Marine Environment Against Pollution by Dumping, Protocol on the Protection of the Black Sea Marine Environment Against Pollution From Land-Based Sources	Black Sea Pollution	Commission on the Protection of the Black Sea Against Pollution	Pollution, Ocean, Oil	1992	6	1
Black Sea Biodiversity and Landscape Conservation Protocol to the Convention on the Protection of the Black Sea Against Pollution	Black Sea Pollution	Commission on the Protection of the Black Sea Against Pollution	Habitat, Land, Nature, Pollution, Ocean, Oil, Species	2002	4	1
Protocol on the Protection of the Marine Environment of the Black Sea from Land-Based Sources and Activities	Black Sea Pollution	Commission on the Protection of the Black Sea Against Pollution	Nature, Ocean, Pollution, Oil	2009	1	1
Agreement Establishing the Caribbean Community Climate Change Centre	Caribbean Community Climate Change Centre	Caribbean Community Climate Change Centre	Pollution, Air, Organisation, Region	2002	8	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement Establishing the Caribbean Environmental Health Institute	Caribbean Environmental Health Institute	Caribbean Environmental Health Institute	Nature, Region	1980	14	1
Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	Caribbean Marine Protection	UNEP Caribbean Environment Programme	Nature, Ocean, Region	1983	25	1
Protocol Concerning Cooperation in Combating Oil Spills in the Wider Caribbean Region	Caribbean Marine Protection	UN EP Caribbean Environment Programme	Pollution, Ocean, Oil, Region	1983	25	1
Protocol Concerning Specially Protected Areas and Wildlife to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	Caribbean Marine Protection	UNEP Caribbean Environment Programme	Habitat, Nature, Ocean, Species, Region	1990	16	1
Protocol Concerning Pollution From Land-Based Sources and Activities to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	Caribbean Marine Protection	UNEP Caribbean Environment Programme	Pollution	1999	10	1
Agreement E stablishing the Caribbean Regional Fisheries Mechanism	Caribbean Regional Fisheries	Caribbean Regional Fisheries Mechanism Secretariat	Species, Fauna, Fish, Region	2002	11	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Framework Convention on the Protection and Sustainable Development of the Carpathians	Carpathian Sustainable Development	Interim Secretariat of the Framework Convention on the Protection and Sustainable Development of the Carpathians	Nature	2003	7	1
Protocol on Conservation and Sustainable Use of Biological and Landscape Diversity to the Framework Convention on the Protection and Sustainable Development of the Carpathians	Carpathian Sustainable Development	Interim Secretariat of the Framework Convention on the Protection and Sustainable Development of the Carpathians	Species	2008	7	1
Protocol on Sustainable Forest Management to the Framework Convention on the Protection and Sustainable Development of the Carpathians	Carpathian Sustainable Development	Interim Secretariat of the Framework Convention on the Protection and Sustainable Development of the Carpathians	Species, Flora	2011	6	1
Protocol on Sustainable Tourism to the Framework Convention on the Protection and Sustainable Development of the Carpathians	Carpathian Sustainable Development	Interim Secretariat of the Framework Convention on the Protection and Sustainable Development of the Carpathians	Nature, Region	2011	6	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol on Sustainable Transport to the Framework Convention on the Protection and Sustainable Development of the Carpathians	Carpathian Sustainable Development	Interim Secretariat of the Framework Convention on the Protection and Sustainable Development of the Carpathians	Nature, Region	2014	3	1
Framework Convention for the Protection of the Marine Environment of the Caspian Sea	Caspian Sea	Caspian Environment Programme	Nature, Ocean, Region	2003	5	1
Protocol concerning Regional Preparedness, Response and Co-Operation in combating Oil Pollution Incidents to the Framework Convention on the Protection of the Marine Environment of the Caspian Sea	Caspian Sea	Caspian Environment Programme	Pollution, Ocean, Oil	2011	5	1
Protocol for the Protection of the Caspian Sea against Pollution from Land based Sources and Activities to the Framework Convention on the Protection of the Marine Environment of the Caspian Sea	Caspian Sea	Caspian Environment Programme	Pollution, Accident, Ocean, Region	2012	3	1
Protocol for the Conservation of Biological Diversity to the Framework Convention on the Protection of the Marine Environment of the Caspian Sea	Caspian Sea	Caspian Environment Programme	Nature, Ocean	2014	1	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Constitutional Agreement of the Central American Commission on Environment and Development	CCAD	Comision Centroamericana de Ambiente y Desarrollo	Nature, Organisation	1989	6	1
Protocol to the Constituent Agreement of the Central American Commission on Environment and Development	CCAD	Comision Centroamericana de Ambiente y Desarrollo	Nature, Organisation	1991	5	1
Constitutional Agreement of the Central American Interparliamentary Commission for Environment and Development	CCAD	Comision Centroamericana de Ambiente y Desarrollo	Nature, Organisation	1991	2	1
Convention for the Conservation of the Biodiversity and the Protection of Priority Wilderness Areas in Central America	CCAD	Comision Centroamericana de Ambiente y Desarrollo	Nature, Species	1992	6	1
Central American Regional Agreement on the Transboundary Movement of Hazardous Wastes	CCAD	Comision Centroamericana de Ambiente y Desarrollo	Pollution, Wastes, Territory	1992	6	1
Protocol on cooperation in natural resources between member states of the Economic Community of Central African States	Central African States	Economic Community of Central African States	Nature, Organisation, Region	1983	10	1
Treaty on the Conservation and Sustainable Development of the Forest Ecosystems of Central Africa	Central African States	Economic Community of Central African States	Nature, Species, Flora, Region	2005	8	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement for Cooperation and Consultation Between the Central African States for the Conservation of Wild Fauna	Central African Wild Fauna	Organisation pour la Conservation de la Faune Sauvage en Afrique Centrale (Conseil de l'Entente)	Nature, Species, Fauna, Region	1983	0	1
Regional Convention on Climate Change	Central American Climate Change	Secretaría General del Sistema de la Integracion Centroamericana	Pollution, Air	1993	7	1
Regional Convention for the Management and Conservation of the Natural Forest Ecosystems and the Development of Forest Plantations	Central American Conservation Natural Forest Ecosystems	Consejo Centroamericano de Bosques y Areas Protegidas	Nature, Species, Flora	1993	5	1
Agreement on Cooperation in the Area of Environment and Rational Nature Use	Central Asia Environmental Cooperation	No Secretariat established	Nature	1998	3	1
Accord establishing a uniform river regime and creating CICOS	CICOS	Commission Internationale du Bassins Congo-Oubangui-Sangha	Freshwater, Nature	1999	6	1
Protocol to the Accord establishing a uniform river regime and creating CICOS	CICOS	Commission Internationale du Bassins Congo-Oubangui-Sangha	Freshwater, Nature, Pollution, Air	2007	0	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement on cooperation in the field of ecology and environmental protection	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature	1992	11	1
Agreement on Cooperation in the Field of Prevention of and Response to Emergencies of Natural and Technological Disasters	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Pollution, Accident	1993	12	1
Agreement on information cooperation in the area of ecology and environment protection and Agreement on cooperation in the forestry sector and forestry	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature, Species, Flora	1998	7	1
Agreement on basic principles of mutual activity in the area of the rational use and protection of transboundary water bodies	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Freshwater, Territory	1998	4	1
Agreement on cooperation in the area of environmental monitoring	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature, Enforcement, Organisation	1999	6	1
Agreement on cooperation in the area of preservation and use of genetic resources of cultured plants of member states of the CIS	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Species, Agriculture, Flora	1999	9	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement on cooperation in the field of active influence of meteorological and other geophysical processes (environmental modification)	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Pollution, Air	2001	7	1
Agreement on Interstate hydrometeorological network of the Commonwealth of Independent States	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature	2001	8	1
Agreement on cross-border cooperation in the field of research, development and protection of natural resources	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature	2001	5	1
Agreement on cooperation in the field of industrial safety of hazardous production facilities	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature	2001	8	1
Agreement on cooperation in the field of environmental protection among the member-states of the Commonwealth of Independent States	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature	2013	3	1
Protocol amending the Agreement on cooperation in the field of ecology and environmental protection	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature	2002	5	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol amending the Agreement on cooperation in the area of environmental monitoring	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Nature, Enforcement, Organisation	2005	0	1
Agreement on the Control of Transboundary Shipments of Hazardous and Other Wastes Between States Members of the Commonwealth of Independent States	CIS Environmental Agreements	Secretariat of the Commonwealth of Independent States	Pollution, Wastes, Ocean, Territory	1996	7	1
Convention on International Trade in Endangered Species of Wild Fauna and Flora	CITES	CITES Secretariat	Species, Fauna, Flora	1973	184	0
Convention on Civil Liability for Damage Resulting From Activities Dangerous to the Environment	Civil Liability Activities Dangerous to the Environment	Council of Europe	Nature, Pollution, General	1993	0	1
International Convention on Civil Liability for Bunker Oil Pollution Damage	Civil Liability Bunker Oil Pollution	International Maritime Organisation (IMO)	Pollution, Ocean, Oil, General	2001	81	0
United Nations Framework Convention on Climate Change	Climate Change	Secretariat of the UN Convention of Climate Change	Pollution, Air	1992	197	0
Kyoto Protocol to the United Nations Framework Convention on Climate Change	Climate Change	Secretariat of the UN Convention of Climate Change	Pollution, Ocean, Oil, General	1997	181	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Paris Agreement under the United Nations Framework Convention on Climate Change	Climate Change	Secretariat of the UN Convention of Climate Change	Pollution, Air	2015	125	0
Convention on the Conservation of Migratory Species of Wild Animals	Conservation Migratory Species	UNEP CMS Secretariat	Nature, Species, Fauna	1979	79	0
Agreement on the Conservation of Populations of European Bats	Conservation Migratory Species	Eurobats Secretariat	Nature, Species, Fauna, Mammals	1991	36	1
Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas	Conservation Migratory Species	ASCOBANS	Nature, Species, Fauna, Mammals, Region	1992	10	1
Agreement on the Conservation of African-Eurasian Migratory Waterbirds	Conservation Migratory Species	African-Eurasian Waterbird Agreement Secretariat	Nature, Species, Fauna, Mammals, Marine, Fish	1995	76	1
Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area	Conservation Migratory Species	ACCOBAMS Secretariat	Nature, Species, Fauna, Mammals, Marine, Fish, Ocean, Region	1996	23	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement on the Conservation of Gorillas and Their Habitats	Conservation Migratory Species	UNEP CMS Secretariat	Species, Fauna, Mammals	1996	7	1
Convention on Cooperation for Protection and Sustainable Use of the Danube River	Danube	International Commission for the Protection of the Danube	Freshwater, Nature	1994	15	1
Convention Between the Governments of the Hungarian People's Republic and the Czechoslovakian Socialist Republic, the Executive Council of the Yugoslav Socialist Federal Republic, the Governments of the Romanian Socialist Republic and of the Union of Soviet Socialist Republics on Measures to Combat Pollution of the Tisza River and Its Tributaries	Danube	International Commission for the Protection of the Danube	Freshwater, Pollution, Organisation	1986	0	1
Convention to Combat Desertification in Those Countries Experiencing Serious Drought and, or Desertification, Particularly in Africa	Desertification	Secretariat of the UN Convention to Combat Desertification	Habitat, Land, Region	1994	196	0
Amendment Adding Annex V to the Convention to Combat Desertification in Those Countries Experiencing Serious Drought and, or Desertification, Particularly in Africa	Desertification	Secretariat of the UN Convention to Combat Desertification	Habitat, Land, Region	2000	199	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention for the Prohibition of Fishing With Long Driftnets in the South Pacific	Driftnet Fishing	South Pacific Forum Fisheries Agency	Species, Fauna, Fish, Ocean, Region	1986	13	1
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	Dumping of Wastes and Other Matter	London Convention Secretariat	Pollution, Ocean, Wastes	1972	7	0
Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	Dumping of Wastes and Other Matter	London Convention Secretariat	Pollution, Ocean, Wastes	1996	46	0
Protocol for Sustainable Development of Lake Victoria Basin to the Treaty for the Establishment of the East African Community	East African Community	East African Community	Freshwater, Nature, Organisation, Region	2003	3	1
Protocol on Environment and Natural Resources Management to the Treaty for the Establishment of the East African Community	East African Community	East African Community	Nature	2006	2	1
Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region	Eastern African Marine Environment	UNEP Regional Coordinating Unit for the Eastern African Action Plan (EAF, RCU)	Nature, Ocean, Region	1985	10	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Amended Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean (formerly the Eastern African Region)	Eastern African Marine Environment	UNEP Regional Coordinating Unit for the Eastern African Action Plan (EAF, RCU)	Nature, Ocean, Region	2010	0	1
Agreement on the Regional Contingency Plan for Preparedness for and Response to major Marine Pollution Incidents in the Western Indian Ocean	Eastern African Marine Environment	UNEP Regional Coordinating Unit for the Eastern African Action Plan (EAF, RCU)	Pollution, Accident, Ocean, Region	2011	9	1
Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques	ENMOD	United Nations Department of Disarmament Affairs	Nature	1977	80	0
Convention on Environmental Impact Assessment in A Transboundary Context	Environmental Impact Assessment	UN Economic Commission for Europe (UNECE)	Nature, Territory	1991	45	1
Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context	Environmental Impact Assessment	UN Economic Commission for Europe (UNECE)	Nature, Territory	2003	30	1
European Convention for the Protection of Animals Kept for Farming Purposes	European Animals Farming	Council of Europe	Species, Agriculture, Fauna, Region	1976	33	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol of Amendment to the European Convention for the Protection of Animals Kept for Farming Purposes	European Animals Farming	Council of Europe	Species, Agriculture, Fauna, Region	1992	18	1
European Convention for the Protection of Animals for Slaughter	European Animals Slaughter	Council of Europe	Species, Fauna, Region	1979	25	1
European Agreement on the Restriction of the Use of Certain Detergents in Washing and Cleaning Products	European Detergents	Council of Europe	Freshwater, Pollution, Region	1968	10	1
Protocol Amending the European Agreement on the Restriction of the Use of Certain Detergents in Washing and Cleaning Products	European Detergents	Council of Europe	Freshwater, Pollution, Region	1983	6	1
European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes	European Experimental Animals	Council of Europe	Species, Fauna, Region	1986	22	1
Protocol of Amendment to the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes	European Experimental Animals	Council of Europe	Species, Fauna, Region	1998	19	1
Convention on the European Forest Institute	European Forest Institute	European Forest Institute	Species, Flora, Organisation	2003	25	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
European Landscape Convention	European Landscape	Council of Europe	Habitat, Land, Region	2000	38	1
Convention for the Establishment of the European and Mediterranean Plant Protection Organisation	European Plant Protection	European and Mediterranean Plant Protection Organisation (EPPO)	Species, Flora, Ocean, Region, Organisation	1951	52	1
Convention on the Conservation of European Wildlife and Natural Habitats	European Wildlife Habitat	Council of Europe Secretariat for the Bern Convention	Habitat, Nature, Species, Region	1979	51	1
Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing	FAO Unregulated Fisheries	Food and Agriculture Organisation (FAO)	Species, Fauna, Fish	2009	36	0
Agreement to Promote Compliance With International Conservation and Management Measures by Fishing Vessels on the High Seas	Fisheries Compliance High Seas	Food and Agriculture Organisation (FAO)	Nature, Species, Fauna, Fish	1993	40	0
Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal	Hazardous Wastes	Secretariat of the Basel Convention	Pollution, Wastes, Territory	1989	184	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention on the Conservation and Management of the Highly Migratory Fish Stocks of the Western and Central Pacific Ocean	Highly Migratory Fish Stocks Western Central Pacific	Western and Central Pacific Ocean Fisheries Commission	Nature, Species, Fauna, Fish, Ocean, Region	2000	26	1
Agreement Establishing the Inter-American Institute for Global Change Research	Inter-American Institute for Global Change Research	Organisation of American States (OAS)	Nature	1992	19	1
Inter-American Convention for the Protection and Conservation of Sea Turtles	Inter-American Turtles	IAC SeaTurtle	Nature, Species, Fauna, Fish, Ocean	1996	15	1
Convention on the International Hydrographic Organisation	International Hydrographic Organisation	International Hydrographic Organisation	Ocean, Organisation	1967	85	0
Statutes of the Intergovernmental Oceanographic Commission	International Oceanographic Commission	International Oceanographic Commission	Ocean, Organisation	1960	148	0
International Plant Protection Convention	International Plant Protection	International Plant Protection Convention Secretariat	Species, Flora	1951	99	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
International Plant Protection Convention (1979 Revised Text)	International Plant Protection	International Plant Protection Convention Secretariat	Species, Flora	1979	141	0
International Plant Protection Convention, Regional South Cone	International Plant Protection South Cone	South Cone Plant Protection Commission	Species, Flora	1989	7	1
Statute of the International Renewable Energy Agency	International Renewable Energy Agency	International Renewable Energy Agency	Energy	2009	149	0
Agreement establishing the International Tropical Timber Bureau	International Tropical Timber	International Tropical Timber Organisation	Species, Flora	1977	0	0
International Tropical Timber Agreement	International Tropical Timber	International Tropical Timber Organisation	Species, Flora	1983	53	0
International Tropical Timber Agreement	International Tropical Timber	International Tropical Timber Organisation	Species, Flora	1994	70	0
International Tropical Timber Agreement	International Tropical Timber	International Tropical Timber Organisation	Species, Flora	2006	75	0
Protocol to the International Convention for the Regulation of Whaling	International Whaling	International Whaling Commission	Species, Fauna, Mammals, Marine, Fish	1956	90	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment From Pollution	Kuwait Marine Pollution	Regional Organisation for the Protection of the Marine Environment (ROPME)	Nature, Ocean, Pollution	1978	8	1
Protocol Concerning Marine Pollution Resulting From Exploration and Exploitation of the Continental Shelf to the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment From Pollution	Kuwait Marine Pollution	Regional Organisation for the Protection of the Marine Environment (ROPME)	Pollution, Ocean	1989	8	1
Protocol for the Protection of the Marine Environment Against Pollution From Land-Based Sources to the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment From Pollution	Kuwait Marine Pollution	Regional Organisation for the Protection of the Marine Environment (ROPME)	Nature, Ocean, Pollution	1990	6	1
Protocol on the Control of Marine Transboundary Movements and Disposal of Hazardous Wastes and Other Wastes to the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment From Pollution	Kuwait Marine Pollution	Regional Organisation for the Protection of the Marine Environment (ROPME)	Nature, Ocean, Pollution, Wastes, Territory	1998	6	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Agreement for the Establishment on A Permanent Basis of A Latin-American Forest Research and Training Institute	Latin-American Forest Research and Training Institute	Instituto Forestal LatinoAmericano	Species, Flora	1959	18	1
International Convention on Liability and Compensation for Damage in Connection With the Carriage of Hazardous and Noxious Substances by Sea	Liability Compensation Hazardous and Noxious Substances	International Maritime Organisation (IMO)	Pollution, General	1996	14	0
Protocol to the International Convention on Liability and Compensation for Damage in Connection With the Carriage of Hazardous and Noxious Substances by Sea	Liability Compensation Hazardous and Noxious Substances	International Maritime Organisation (IMO)	Pollution, General	2010	1	0
Convention on the Conservation of the Living Resources of the Southeast Atlantic	Living Resources of Southeast Atlantic	International Commission for the Southeast Atlantic Fisheries (ICSEAF)	Nature	1969	17	0
Protocol Modifying the International Convention for the Permanent Control of Outbreak Areas of the Red Locust	Locusts	International Red Locust Control Organisation for Central and Southern Africa	Species, Agriculture, Flora	1953	4	1
Convention for the Establishment of the Desert Locust Control Organisation for Eastern Africa	Locusts	Desert Locust Control Organisation for Eastern Africa	Species, Agriculture, Flora	1962	9	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention on the African Migratory Locust	Locusts	International Red Locust Control Organisation for Central and Southern Africa	Species, Agriculture, Flora, Organisation, Region	1962	8	1
Agreement for the Establishment of A Commission for Controlling the Desert Locust in the Near East (Central Region)	Locusts	Commission for Controlling the Desert Locust in the Central Region (formerly Near East)	Species, Agriculture, Flora, Organisation	1965	16	1
Agreement for the Establishment of A Commission for Controlling the Desert Locust in Northwest Africa	Locusts	Commission for Controlling the Desert Locust in Northwest Africa	Species, Agriculture, Flora, Organisation, Region	1970	5	1
Agreement for the Establishment of A Commission for Controlling the Desert Locust in the Western Region	Locusts	Food and Agriculture Organisation (FAO)	Species, Agriculture, Flora, Organisation	2000	10	1
Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1979	55	1
Protocol on the Reduction of Sulphur Emissions or Their Transboundary Fluxes by At Least 30 Per Cent to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1985	55	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol Concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1988	56	1
Protocol Concerning the Control of Emissions of Volatile Organic Compounds or Their Transboundary Fluxes to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1991	24	1
Protocol on Further Reduction of Sulphur Emissions to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1994	29	1
Protocol on Heavy Metals to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1998	32	1
Protocol on Persistent Organic Pollutants to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Pollution, Air, Territory	1998	32	1
Protocol to Abate Acidification, Eutrophication and Ground-Level Ozone to the Convention on Long-Range Transboundary Air Pollution	LRTAP	LRTAP Secretariat of UNECE	Freshwater, Pollution, Air, Territory	1999	26	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention for Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	Marine Environment West Central Africa	Regional Coordinating Unit for West and Central African Action Plan (WACAF, RCU)	Nature, Ocean, Region	1981	18	1
Protocol Concerning Cooperation in Combating Pollution in Cases of Emergency	Marine Environment West Central Africa	Regional Coordinating Unit for West and Central African Action Plan (WACAF, RCU)	Pollution, accident	1981	13	1
Additional Protocol to the Abidjan Convention Concerning Cooperation in the Protection and Development of Marine and Coastal Environment from Land-Based Sources and Activities in the Western, Central, and Southern African Region	Marine Environment West Central Africa	Regional Coordinating Unit for West and Central African Action Plan (WACAF, RCU)	Pollution, accident	2012	2	1
International Convention for the Prevention of Pollution of the Sea by Oil	MARPOL	International Maritime Organisation (IMO)	Pollution, Ocean, Oil	1954	75	0
International Convention for the Prevention of Pollution From Ships (MARPOL)	MARPOL	International Maritime Organisation (IMO)	Pollution, Ocean	1973	32	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol to the International Convention for the Prevention of Pollution From Ships - Protocol and Annexes I and II	MARPOL	International Maritime Organisation (IMO)	Pollution, Ocean	1978	152	0
Protocol Adopting Annex VI - Regulations for the Prevention of Air Pollution From Ships to the International Convention for the Prevention of Pollution From Ships	MARPOL	International Maritime Organisation (IMO)	Pollution, Air, Ocean	1997	87	0
International Convention on the Control of Harmful Anti-Fouling Systems on Ships	MARPOL	International Maritime Organisation (IMO)	Pollution, Ocean	2001	73	0
International Convention for the Control and Management of Ships' Ballast Water and Sediments	MARPOL	International Maritime Organisation (IMO)	Pollution, Freshwater, Ocean	2004	52	0
International Convention for the Safe and Environmentally Sound Recycling of Ships	MARPOL	International Maritime Organisation (IMO)	Pollution, Ocean, Wastes	2009	5	0
Convention for the Protection of the Mediterranean Sea Against Pollution	MedPlan	UNEP Mediterranean Action Plan	Pollution, Ocean, Region	1976	23	1
Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping From Ships and Aircraft	MedPlan	UNEP Mediterranean Action Plan	Pollution, Ocean, Region	1976	23	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol Concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency	MedPlan	UNEP Mediterranean Action Plan	Pollution, Ocean, Oil, Wastes, Accident, Region	1976	23	1
Protocol for the Protection of the Mediterranean Sea Against Pollution From Land-Based Sources	MedPlan	UNEP Mediterranean Action Plan	Pollution, Ocean, Region	1980	23	1
Protocol Concerning Mediterranean Specially Protected Areas	MedPlan	UNEP Mediterranean Action Plan	Habitat, Ocean, Region	1982	21	1
Protocol for the Protection of the Mediterranean Sea Against Pollution Resulting From Exploration and Exploitation of the Continental Shelf and the Seabed and Its Subsoil	MedPlan	UNEP Mediterranean Action Plan	Pollution, Ocean, Region	1994	6	1
Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean	MedPlan	UNEP Mediterranean Action Plan	Habitat, Species, Ocean, Region	1995	18	1
Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and Their Disposal	MedPlan	UNEP Mediterranean Action Plan	Pollution, Wastes, Ocean, Region, Territory	1996	7	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol Concerning Co-operation in Preventing Pollution From Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea	MedPlan	UNEP Mediterranean Action Plan	Pollution, Ocean, Accident, Region	2002	15	1
Protocol on Integrated Coastal Zone Management in the Mediterranean	MedPlan	UNEP Mediterranean Action Plan	Pollution, Wastes, Ocean, Region, Territory	2008	9	1
Minamata Convention on Mercury	Mercury	Minamata Mercury Secretariat	Nature	2013	72	0
Convention for the Conservation of Salmon in the North Atlantic Ocean	NASCO	North Atlantic Salmon Conservation Organisation	Nature, Species, Fauna, Fish, Ocean	1982	10	1
Protocol Open for Signature by States not Parties to the Convention for the Conservation of Salmon in the North Atlantic Ocean	NASCO	North Atlantic Salmon Conservation Organisation	Nature, Species, Fauna, Fish, Ocean	1992	0	1
Agreement on the Establishment of the Near East Plant Protection Organisation	Near East Plant Protection	Near East Plant Protection Organisation	Species, Flora, Organisation	1993	12	1
International Convention for the Protection of New Varieties of Plants	New Varieties of Plants	International Union for the Protection of New Varieties of Plants (UPOV)	Species, Flora	1961	8	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention on the Law of the Non-Navigational Uses of International Watercourses	Non-Navigational Uses of International Watercourses	United Nations International Law Commission	Freshwater, Pollution, Nature	1997	35	0
Convention for A North Pacific Marine Science Organisation	North Pacific Marine Science Organisation	North Pacific Marine Science Organisation	Ocean, Organisation	1990	6	1
Agreement for Cooperation in Dealing With Pollution of the North Sea by Oil	North Sea Oil	Bonn Agreement Secretariat	Pollution, Ocean, Oil	1969	8	1
Agreement for Cooperation in Dealing With Pollution of the North Sea by Oil and Other Harmful Substances	North Sea Oil	Bonn Agreement Secretariat	Pollution, Ocean, Oil, Wastes	1983	10	1
Convention on the Conduct of Fishing Operations in the North Atlantic	North Seas Fishery		Species, Fauna, Fish	1967	16	1
Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific	Northeast Pacific Marine Environment Sustainable Development	Central American Commission for Maritime Transportation	Nature, Ocean	2002	2	1
International Convention on Civil Liability for Oil Pollution Damage	Oil Pollution Civil Liability	IOPC Funds Secretariat	Pollution, Ocean, Oil, General	1969	104	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol to the International Convention on Civil Liability for Oil Pollution Damage	Oil Pollution Civil Liability	IOPC Funds Secretariat	Pollution, Ocean, Oil, General	1976	59	0
Protocol to Amend the International Convention on Civil Liability for Oil Pollution Damage	Oil Pollution Civil Liability	IOPC Funds Secretariat	Pollution, Ocean, Oil, General	1984	10	0
Protocol to Amend the International Convention on Civil Liability for Oil Pollution Damage	Oil Pollution Civil Liability	IOPC Funds Secretariat	Pollution, Ocean, Oil, General	1992	136	0
International Convention on the Establishment of An International Fund for Compensation for Oil Pollution Damage	Oil Pollution Fund	IOPC Funds Secretariat	Pollution, Ocean, Oil	1971	72	0
Protocol to Amend the International Convention on the Establishment of An International Fund for Compensation for Oil Pollution Damage (replacing the 1971 Convention)	Oil Pollution Fund	IOPC Funds Secretariat	Pollution, Ocean, Oil	1992	113	0
Protocol to Amend the 1992 International Convention on the Establishment of An International Fund for Compensation for Oil Pollution Damage	Oil Pollution Fund	IOPC Funds Secret	Pollution, Ocean, Oil	2003	31	0
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties	Oil Pollution Intervention	International Maritime Organisation (IMO)	Pollution, Ocean, Oil	1969	88	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol Relating to Intervention on the High Seas in Cases of Pollution by Substances Other Than Oil	Oil Pollution Intervention	International Maritime Organisation (IMO)	Pollution	1973	57	0
Cooperation Agreement for the Protection of the Coasts and Waters of the North-East Atlantic Against Pollution	Oil Pollution Northeast Atlantic	Centro Internacional de Luta contra a Poluição marítima no Atlântico Nordeste (International Center for pollution combat in the Northeast Atlantic)	Pollution, Freshwater	1990	4	1
Additional Protocol to the Cooperation Agreement for the Protection of the Coasts and Waters of the North-East Atlantic Against Pollution	Oil Pollution Northeast Atlantic	Centro Internacional de Luta contra a Poluição marítima no Atlântico Nordeste (International Center for pollution combat in the Northeast Atlantic)	Pollution, Freshwater	2008	5	1
International Convention on Oil Pollution Preparedness, Response and Cooperation	Oil Pollution Preparedness	International Maritime Organisation (IMO)	Pollution, Ocean, Oil	1990	107	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol on Preparedness, Response and Cooperation to Pollution Incidents by Hazardous and Noxious Substances	Oil Pollution Preparedness	International Maritime Organisation (IMO)	Pollution	2000	37	0
Convention on Civil Liability for Oil Pollution Damage Resulting From Exploration for and Exploitation of Seabed Mineral Resources	Oil Pollution Seabed Minerals	Depositary: UKFCO	Pollution, Ocean, Oil, Environment, Nature, General	1977	0	1
Convention for the Prevention of Marine Pollution by Dumping From Ships and Aircraft	Oslo-Paris Marine Pollution	Joint Secretariat of PARCOM and OSCOM	Pollution, Ocean	1972	13	1
Convention on the Prevention of Marine Pollution From Land-Based Sources	Oslo-Paris Marine Pollution	Joint Secretariat of PARCOM and OSCOM	Pollution, Ocean	1974	12	1
Protocol Amending the Convention for the Prevention of Marine Pollution by Dumping From Ships and Aircraft	Oslo-Paris Marine Pollution	Joint Secretariat of PARCOM and OSCOM	Pollution, Ocean	1983	10	1
Protocol to the Convention on the Prevention of Marine Pollution From Land-Based Sources	Oslo-Paris Marine Pollution	Joint Secretariat of PARCOM and OSCOM	Pollution, Ocean	1986	13	1
Protocol Amending the Convention for the Prevention of Marine Pollution by Dumping From Ships and Aircraft	Oslo-Paris Marine Pollution	Joint Secretariat of PARCOM and OSCOM	Pollution, Ocean	1989	11	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention for the Protection of the Marine Environment of the North East Atlantic	Oslo-Paris Marine Pollution	Joint Secretariat of PARCOM and OSCOM	Nature, Ocean	1992	16	1
Convention for the Protection of the Ozone Layer	Ozone Protection	Ozone Secretariat	Pollution, Air	1985	190	0
Montreal Protocol on Substances That Deplete the Ozone Layer	Ozone Protection	Ozone Secretariat	Pollution, Air	1987	197	0
Plant Protection Agreement for the Asia and Pacific Region	Pacific Plant Protection	Asia and Pacific Plant Protection Commission	Species, Flora, Region	1956	23	1
Agreement on the Organisation of the Permanent Commission of the Conference on the Exploitation and Conservation of the Maritime Resources of the South Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Nature, Species, Fauna, Fish, Ocean, Organisation, Region	1952	4	1
Agreement Relating to the Issue of Permits for the Exploitation of the Maritime Resources of the South Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Species, Fauna, Fish, Ocean, Region	1954	3	1
Agreement Relating to Regulations Governing Whaling in the Waters of the South Pacific Under the Permanent Commission of the South Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Species, Fauna, Mammals, Marine, Fish, Freshwater, Region	1954	1	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention for the Protection of the Marine Environment and Coastal Area of the Southeast Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Nature, Ocean	1981	5	1
Protocol for the Protection of the Southeast Pacific Against Pollution From Land-Based Sources	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Pollution	1983	5	1
Protocol for the Conservation and Management of the Protected Marine and Coastal Areas of the Southeast Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Nature, Ocean	1989	5	1
Framework Agreement for the Conservation of the Living Marine Resources of the High Seas of the Southeast Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Nature, Species, Fauna, Fish, Ocean, Region	2000	3	1
Protocol Amending the Framework Agreement for the Conservation of the Living Marine Resources of the High Seas of the South Pacific	Permanent Commission South Pacific	Permanent Commission of the South Pacific	Nature, Species, Fauna, Fish, Ocean, Region	2003	2	1
Convention on Persistent Organic Pollutants	Persistent Organic Pollutants	UNEP Chemicals	Pollution	2001	167	0
Phytosanitary Convention for Africa South of the Sahara	Phytosanitary South of Sahara	InterAfrican Phytosanitary Council	Species, Agriculture, Flora, Region	1954	26	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Phytosanitary Convention for Africa	Phytosanitary South of Sahara	InterAfrican Phytosanitary Council	Species, Agriculture, Flora, Region	1967	10	1
Agreement on the Establishment of the International Plant Genetic Resources Institute	Plant Genetic Resources	Commission on Genetic Resources for Food and Agriculture	Species, Agriculture, Flora	1991	11	0
International Treaty on Plant Genetic Resources for Food and Agriculture	Plant Genetic Resources	Commission on Genetic Resources for Food and Agriculture	Species, Agriculture, Flora	2001	139	0
Agreement on Conservation of Polar Bears	Polar Bear	Norwegian Ministry for the Environment	Nature, Species, Fauna, Mammals	1973	5	1
Convention Placing the International Poplar Commission Within the Framework of the Food and Agriculture Organisation of the United Nations	Poplar Commission in FAO	Food and Agriculture Organisation (FAO)	Species, Agriculture, Flora, Organisation	1959	38	0
Convention Concerning the Prevention of Major Industrial Accidents	Preventing Major Industrial Accidents	International Labour Organisation (ILO)	Pollution, Accident	1993	18	0
Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	Prior Informed Consent Chemicals and Pesticides	Prior Informed Consent Interim Secretariat	Pollution	1998	154	0

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
International Convention for the Protection of Birds	Protection of Birds	United Nations	Species, Fauna, Bird	1950	16	1
Convention on the Protection of the Environment Through Criminal Law	Protection of the Environment Through Criminal Law	Council of Europe	Nature	1998	1	1
Convention on the Protection and Use of Transboundary Watercourses and International Lakes	Protection Transboundary Watercourses	UN Economic Commission for Europe (UNECE)	Freshwater, Pollution, Territory	1992	41	1
Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes	Protection Transboundary Watercourses	UN Economic Commission for Europe (UNECE)	Freshwater, Pollution, Territory	1999	26	1
Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	Public Participation and Justice in Environmental Matters	UN Economic Commission for Europe (UNECE)	Nature	1998	47	1
Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	Public Participation and Justice in Environmental Matters	UN Economic Commission for Europe (UNECE)	Nature, Pollution	2003	32	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment	Red Sea Environment	UNEP Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERGSA)	Nature, Ocean	1982	8	1
Protocol Concerning Regional Cooperation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency	Red Sea Environment	UNEP Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERGSA)	Pollution, Ocean, Oil, Wastes, Accident	1982	7	1
Convention on the Protection of the Rhine Against Pollution by Chlorides	Rhine Pollution	International Commission for the Protection of the Rhine	Freshwater, Pollution	1976	5	1
Convention for the Protection of the Rhine Against Chemical Pollution	Rhine Pollution	International Commission for the Protection of the Rhine	Freshwater, Pollution	1976	6	1
Protocol Additional to the Convention for the Protection of the Rhine From Pollution by Chlorides	Rhine Pollution	International Commission for the Protection of the Rhine	Freshwater, Pollution	1991	7	1
Convention on the Protection of the Rhine	Rhine Pollution	International Commission for the Protection of the Rhine	Freshwater, Pollution	1999	6	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention Establishing A Permanent Inter-State Drought Control Committee for the Sahel	Sahel Drought Control	Permanent Interstate Committee for Drought Control in the Sahel	Habitat, Land, Organisation	1973	6	1
Revised Convention of the Permanent Inter-State Drought Control Committee for the Sahel	Sahel Drought Control	Permanent Interstate Committee for Drought Control in the Sahel	Habitat, Land, Organisation	1994	6	1
Articles of Association of the South Asia Cooperative Environment Programme	South Asia Cooperative Environment Programme	South Asia Cooperative Environment Programme (SACEP)	Nature, Organisation, Region	1981	8	1
Convention to Ban the Importation into the Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes Within the South Pacific Region	South Pacific Hazardous Wastes	South Pacific Regional Environment Program	Energy, Nuclear, Pollution, Wastes, Region, Territory	1995	12	1
Convention for the Protection of the Natural Resources and Environment of the South Pacific Region	South Pacific Natural Environment	South Pacific Regional Environment Program	Nature, Region	1986	12	1
Protocol for the Prevention of Pollution of the South Pacific Region by Dumping	South Pacific Natural Environment	South Pacific Regional Environment Program	Pollution, Region	1986	11	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Protocol Concerning Co-operation in Combating Pollution Emergencies in the South Pacific Region	South Pacific Natural Environment	South Pacific Regional Environment Program	Pollution, Region	1986	12	1
Convention on Conservation of Nature in the South Pacific	South Pacific Nature	South Pacific Regional Environment Program	Nature, Region	1976	5	1
Agreement Establishing the South Pacific Regional Environment Programme	South Pacific Regional Environment Programme	South Pacific Regional Environment Program	Nature, Region	1993	19	1
Protocol on Wildlife Conservation and Law Enforcement to the Treaty of the Southern African Development Community	Southern African Development Community	Southern African Development Community	Nature, Species, Enforcement, Organisation, Region	1993	10	1
Protocol on Forestry to the Treaty of the Southern African Development Community	Southern African Development Community	Southern African Development Community	Species, Flora, Organisation, Region	2002	10	1
Convention on the Transboundary Effects of Industrial Accidents	Transboundary Effects of Industrial Accidents	UN Economic Commission for Europe (UNECE)	Pollution, Accident, Territory	1992	41	1

Treaty information (continued)

Name	Lineage	Secretariat	Subject	Year	Ratifiers	Regional
Convention for the Conservation of Vicuna	Vicuña Management	Comision Tecnico-Administradora del Convenio de la Vicuña	Nature, Species, Fauna, Mammals	1969	3	1
Convention for the Conservation and Management of the Vicuna	Vicuña Management	Comision Tecnico-Administradora del Convenio de la Vicuña	Nature, Species, Fauna, Mammals	1979	3	1
Convention on Wetlands of International Importance Especially As Waterfowl Habitat	Wetlands	Ramsar Convention Bureau	Habitat, Land, Species, Fauna, Bird, Freshwater	1971	170	0
Convention for the Protection of the World Cultural and Natural Heritage	World Heritage	UNESCO World Heritage Center	Nature, Culture	1972	192	0
World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures	World Trade Organisation	WTO Phytosanitary Secretariat	Species, Agriculture, Flora, Region	1994	164	0
Agreement on the Action Plan for the Environmentally Sound Management of the Common Zambezi River System	Zambezi Watercourse Commission	Southern African Development Community	Freshwater, Nature	1987	5	1
Agreement on the Establishment of the Zambezi Watercourse Commission	Zambezi Watercourse Commission	Zambezi Watercourse Commission	Freshwater, Nature	2004	7	1

Appendix C

Codebook

The table includes a complete list the of variables used in the dissertation. The entries are sorted in alphabetical orders, for each variable the definition and source are provided.

Table C.1: *Definitions and sources*

Variables	Definitions and sources
AgricultureReliance	Value added by agriculture, forestry and fishing as a share of GDP. Data from WDI (World Bank, 2017a).
AnnexI	Dummy that takes the value of 1 if the country is in the Annex I of the UNFCCC (1992).
BiodiversityProtect	Proportion of the important sites for biodiversity that are covered by protected area status. Data from the Goal 15.1 of the SDG (UN, 2017)
Corruption	Corruption score from the International Country Risk Guide (Political Risk Service, 2011).
EnergyDepletion	"Energy Depletion" variable from WDI dataset (World Bank, 2017a). Calculated as the "ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years)". The resources taken into consideration are coal, crude oil, and natural gas.

Definitions and sources (continued)

Variables	Definitions and sources
$\Delta EnergyMix$	Percentage point variation in the electricity production from renewable sources. The energy sources taken into account are geothermal, solar, tides, wind, biomass, and biofuels. International Energy Agency (IEA, 2017).
$EnergyUse$	Energy use per capita, in kg of oil equivalent. Data from the International Energy Agency (IEA, 2017).
$EnvConcern$	Percentage of population that reports being concerned about climate change. Data from Tien et al. (2015) based on a survey conducted in 2007-2008 that covers 119 countries, with 500 to 8000 respondents per country.
$EnvInnovation$	Relative advantage in environment-related technologies. A value of 1 indicates that the country develops environmental technologies as much as the average world invention rate. OECD (2017b).
$EnvPolicyScore$	Score attributed to the sustainability of policies. The score ranges from 1 to 6, with 6 indicating higher levels of importance attributed to sustainability. Country Policy and Institutional Assessment (CPIA) database (International Development Association, 2017)
$ENGO$	Number of ENGOs memberships to the International Union for the Conservation of Nature by country in 2017. We assume a constant value over the entire time period. Data from IUCN website.
$ENGO.Institutions$	Interaction term between $ENGO$ and $Institutions$
$Export$	Total exports of goods and services, measured as share of GDP. Data from WDI (World Bank, 2017a).
$FossilExports$	Export of fossil fuels, ores and metals over the total value of the merchandise export. Data from WDI (World Bank, 2017a).
$FossilSupport$	Government support to fossil fuels (consumption and production) in percentage of tax revenues. "Total fossil support" in OECD Green Growth Indicators dataset (OECD, 2017a).
$FrameworkAgreement$	Dummy variable that takes the value of 1 if the agreement is a framework agreement (typically with non-binding obligations) according to classification from Mitchell (2017).

Definitions and sources (continued)

Variables	Definitions and sources
$FrameworkAgreement$	Dummy variable that takes the value of 1 if the agreement is a framework agreement (typically with non-binding obligations) according to classification from Mitchell (2017).
$FreedomHouseCL$	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).
$FreedomHousePR$	Freedom House index of political rights. On a scale from 1 to 7, where a lower score indicates stronger rights. Freedom House (2017).
$GreenParty$	Share of votes received by the national green party at last elections of the lower house. Own elaboration from data of the Global Election Database (Brancati, 2017). The database contains data for 57 countries. We consider environmental parties all political parties or coalition of parties that contain one of the following words in their name: Green (224), forest (3), climate (0), sustainable (1), earth (8), ecology/ecological (156), nature (14) or environment/environmental/environmentalist (25). In total we selected 381 parties and coalitions.
$IMFresourcerich$	Dummy variable that takes the value of 1 if the country is on the IMF list of resource rich countries (IMF, 2012). The IMF identifies resource-rich countries mainly on the basis of their reliance on the export of natural resources.
$Institutions$	Control of Corruption indicator from the World Governance Indicators (World Bank, 2017b). Expressed in units of a standard normal distribution.
$Institutions2$	Government effectiveness indicator from the World Governance Indicators (World Bank, 2017b). Expressed in units of a standard normal distribution.
$Institutions3$	Economic Freedom Index by Fraser Institute Fraser Institute (2017). Score ranges from 0 to 10. Data is annual from 2000, between 1970 and 2000 only available on a 5 years basis. The missing years are filled by linear interpolation.

Definitions and sources (continued)

Variables	Definitions and sources
$\Delta logCrudeOil$	Differneced logarithm of the Global price of Brent Crude oil on the first of January. Original data expressed in Dollars per barrel. Federal Reserve (2017).
$Land$	Total land surface in thousands squared kilometres. Data from FAO (2017).
$logForest$	Natural logarithm of the forest area, expressed in thousands of squared kilometres. Own calculations from data on the total land surface (FAO, 2017) and the percentage of land covered by forest (World Bank, 2017a).
$logIncome$	Natural logarithm of the GDP per capita in current USD. Data from the UN National account estimates (UNSD, 2017).
$\Delta logIncome$	First difference of the logarithm of GDP per capita in current USD. Data from UN National account estimates (UNSD, 2017).
$RatChina$	Dummy variable that takes the value of 1 if China already ratified the agreement.
$RatGermany$	Dummy variable that takes the value of 1 if Germany already ratified the agreement.
$RatIndia$	Dummy variable that takes the value of 1 if India already ratified the agreement.
$RatRegion$	Share of countries in the same region that ratified the agreement.
$RatRussia$	Dummy variable that takes the value of 1 if Russia already ratified the agreement.
$RatUS$	Dummy variable that takes the value of 1 if the United States already ratified the agreement.
$Regional$	Dummy variable that takes 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).
$ResourceRent$	Sum of fossil fuels rent in percentage of GDP. "Total natural resources rent (%GDP)" in WDI dataset (World Bank, 2017a)

Definitions and sources (continued)

Variables	Definitions and sources
$ResourceRent.Instit$	Interaction term between $ResourceRent$ and $Institutions$
$ShareIndustry$	Share of GDP value added from manufacturing, mining and utilities at current prices. National accounts data (UNSD, 2017).
t	Duration: number of years the treaty-country combination has spent in the risk set.
$ThreatenedSpecies$	Red List Index. The index indicates the conservation status of species groups in a territory. A higher risk of extinction is associated with lower scores. Data from IUCN website (IUCN, 2017).
$\Delta ThreatenedSpecies$	Yearly change in the Red List Index; the index indicates the conservation status of species groups in a territory. A higher risk of extinction is associated with lower scores. Data from IUCN website (IUCN, 2017).