Strategic behavior in IEAs: When and why countries joined the Kyoto Protocol∗

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This version: September 2011

Abstract: We empirically analyze the formation of international environmental agreements within a political economy framework. We develop a theoretical model of state dependent net benefits of ratification that predicts strategic behavior with respect to the timing of ratification and allows us to relate countries’ signing and ratification decisions. Analyzing the signature and ratification process of the Kyoto Protocol via generalized binary and ordered response models, we find significant evidence for our theoretical predictions. In addition, we show that a wide selection of determinants including economic and political factors influences the decision whether to sign and when to ratify.

Keywords: Climate Change, Heteroscedastic Probit Model, International Environmental Agreements, Kyoto Protocol, Partial Proportional Odds Model

JEL-Classification: Q54, F53, C25

∗ We are grateful to Stefan Boes, Thomas Blondiau, Charles Kolstad, Jérémy Laurent-Lucchetti, Edwin Woerdman and participants of the SURED 2010 (Ascona), WCERE 2010 (Montreal) and EALE (Paris) for valuable comments on an earlier draft. Moreover, we would like to thank Michele Baettig for data on the climate change indicator.
1 Introduction

International environmental agreements (IEAs) are an important part of the toolbox of policy makers to combat global environmental problems, as suggested by the pure number of existing treaties.\(^1\) In the context of climate change, however, the difficulties in agreeing on a uniform policy for the post Kyoto era become more and more evident. Although the end of the Kyoto Protocol (KP) is nigh, the international community failed to agree on a succeeding international agreement to reduce greenhouse gas emissions both in December 2009 in Copenhagen and a year later in Cancún.

In order to increase the probability of successful international cooperation in the future, it would be serviceable to better understand the determinants of existing IEAs to enter into force. As the Kyoto Protocol (KP) is so far the only existing international treaty including specific targets for greenhouse gas emissions for at least some developed countries, we empirically analyze its enacting process within a political economy framework.

The key novelty in this paper is that we analyze the ratification process of the KP from a perspective of hindsight. In fact, it turned out that in the case of the KP the crucial issue was not whether but when a country ratified. As former studies considered ratification at most until the year 2003 (e.g. Fredriksson et al. 2007, von Stein 2008), they were not able to observe that the ratification process of the KP splits into three qualitatively different phases, which are determined by two key events: Russia’s announcement to ratify the KP in May 2002 and its actual ratification in November 2004. We introduce a simple model of state dependent net benefits, which explains this discontinuous ratification process by the strategic behavior of countries with particular characteristics and verify it empirically. In addition, we are able to relate the results of both the signing and the ratification stage of the KP and provide evidence on their relative importance. Finally, we refine existing results by finding evidence that both the decision whether to sign and when to ratify are determined by a broad range of observables.

In the present paper, we contribute to the existing literature in several ways. First, the existing literature analyzing IEAs in general and the KP in particular treat the joining decision of individual countries as independent events in binary choice (e.g. Neumayer 2002a,b) or duration (e.g. Fredriksson et al. 2007) models.\(^2\) In general, no accession or a later accession date is interpreted as a lower level of support for the agreement. We argue however, that it

\(^1\) For more information, visit the ENTRI project database at http://sedac.ciesin.columbia.edu/entri.

\(^2\) See also Bernauer et al. (2008) and Roberts et al. (2004) for a recent literature overview. Other treaties these papers examined include the Helsinki Protocol (Murdoch et al. 2003), the Vienna and/or Montreal Protocol (Congleton 1992, Beron et al. 2003), or the Framework Convention on Climate Change (Fredriksson and Gaston 2000, von Stein 2008).
is less total elapsed calendar time that matters, but rather whether ratification took place before or after certain key events. We develop a simple theoretical model of state dependent net benefits of ratification that allows us to distinguish four different categories of countries: class 1 countries unconditionally support the KP; class 2 countries prefer the KP to enter into force but are even better off if it does so without them ratifying; class 3 countries prefer the KP not to enter into force, but given it does, are better off to ratify; finally, class 4 countries are unconditionally harmed by the KP. A country’s class has implications for the timing of ratification. Class 1 countries have no incentive to postpone ratification and should thus do so right away. Class 2 countries should postpone ratification, as they are better off if the KP enters into force without them ratifying. However, as they prefer the KP to enter into force, they should ratify if its enacting is endangered by their reluctance to ratify. Class 3 countries will only ratify when the KP already entered into force or it is apparent that it will do so, and class 4 countries never ratify. We show that, due to the specific design of the KP, the ratification period splits into three distinct phases. In the first phase only class 1 countries are expected to ratify. In the second phase, which starts by Russia’s announcement to ratify the KP and, after the withdrawal of the U.S., can be interpreted as a coordination of the remaining Annex I countries to bring the KP into force, class 2 countries ratified. Russia’s actual ratification of the KP, which also triggered the KP to enter into force marks the beginning of the third phase, in which class 3 countries are expected to ratify. Obviously, class 4 countries never ratify.

Second, to the best of our knowledge, we are the first to analyze both the signing and the ratification stage and are therefore able to relate both determinants. With the exception of Neumayer (2002a,b), empirical studies of IEAs concentrated on the ratification process as the event of accession to the treaty. This seems plausible, as a treaty is only acknowledged under national legislation after ratification. Our theory of state dependent net benefits, however, argues that ratification before or after certain key events signals the degree of support and this level of support may even be lower than the one implied by signing. According to our theoretical model, countries that signed the KP should ratify in the first or second phase, and class 3 countries should never sign the treaty but are expected to ratify in the third phase.\(^3\)

Third, for explaining signing and ratification, we do not ex ante focus on specific aspects like interest groups (Fredriksson et al. 2007), democracy (Congleton 1992, Neumayer 2002a, Midlarsky 1998), trade (Neumayer 2002b), or political entanglement (Bernauer et al. 2008). Instead, we apply a comprehensive economic analysis using a broad set of variables including measures for damage costs of climate change, measures for energy usage, amount of

\(^3\) This is also supported by the fact that so far, 191 countries ratified the KP, with the US being the only prominent exception, but only 84 countries signed it during the signature period.
emissions, and political factors that may influence or are already known to influence international cooperation. This is in line with the theoretical literature on the formation of international environmental agreements, which argues that the net benefits of ratification depend on country specific abatement and damage costs and also on which other countries join the agreement (e.g. Carraro and Siniscalco 1993, Barrett 1994, 1999 and Finus 2001).

Our empirical analysis of the KP supports the predictions of our theoretical model of strategic behavior based on state dependent net benefits of ratification: First, the characteristics of countries ratifying in the three different ratification phases are significantly different. Second, the net benefits of ratification are the lower the later a country ratifies. Third, countries which signed the KP are more likely to ratify in the first and second ratification phase and are less likely to ratify in the third. Finally, a wide range of determinants influences the decision whether to sign and when to ratify, but the predictive power of certain measures differs between the signing and ratification stage.

The remainder of the paper is organized as follows. Section 2 gives a brief introduction to the KP. In Section 3 we develop our theoretical model of state dependent net benefits of ratification and summarize our implications in four testable hypotheses. We elaborate on the data used, the econometric strategy and the estimation results in Section 4. In Section 5, we discuss our findings with respect to our hypotheses. Finally, Section 6 concludes.

2 The Kyoto Protocol in a Nutshell

In the Kyoto Protocol (KP), initially adopted on 11 December 1997, 39 industrialized countries and the European Community, so called Annex B countries, 4 commit to reduce the emissions of four greenhouse gases by 5.2% on average over the period between 2008 to 2012 compared to 1990 levels. It was open for signature between 16 March 1998 and 15 March 1999. Over this period the KP received 84 signatures. Of the 39 countries with reduction commitments, only 3 countries Belarus, Hungary and Iceland did not sign the protocol (Belarus just joined the list of countries with reduction commitments in November 2006). In addition to signature, countries had to ratify the protocol in order to accede to it. Countries which did not sign the protocol during the signature period were able to join it by ratification at any time later on. For entering into force the KP had to satisfy two conditions: It had to be ratified by (i) at least 55 countries, which (ii) represented at least 55% of 1990 global greenhouse gas emissions of Annex I countries.

4 In fact, the list of Annex B countries detailed in the KP with limitations on greenhouse gas emissions is identical to the list of Annex I countries specified in the United Nations Framework Convention on Climate Change (UNFCCC) except for Turkey which is an Annex I but not an Annex B country. In the following, we abstract from this subtle difference and will exclusively use the term Annex I.
The first condition was satisfied on 23 May 2002 when Iceland ratified the KP. In March 2001
the U.S., despite signing the KP, announced not to ratify. As the U.S. were responsible for
36.4% of the 1990 emission levels of Annex I countries, their withdrawal from the ratification
process made Russia – accounting for 17.4% of the 1990 emission levels of Annex I countries
– the pivotal player for reaching the second condition. Although Russia declared to ratify
the KP already in 2002 after the EU-Russia summit, it was not until 4 November 2004 that
Russia’s ratification entered into force – and with it the KP on 16 February 2005, having
now taken both hurdles. Until now, 191 countries and the EU have ratified the KP. The
USA is the only Annex I country which did not ratify the protocol. It is also the only country
which signed the protocol and did not ratify it afterwards.

Figure 1: Number of countries ratifying the KP over time. Histogram of the KP ratification
process (top), kernel density estimates for phase 2 (bottom left) and phase 3 (bottom right).

Figure 1 shows a histogram of the ratification process. We observe that ratification events
are not evenly distributed over time. In fact, we observe increased ratification activity in

\footnote{For a detailed discussion of Russia’s ratification process see, for example, Buchner and Dall’Olio (2005).}

\footnote{San Marino and Somalia, which ratified in 2010, are not included in our data sample.}
the second half of 2002 and in the first half of 2005. We identify two key events (marked by vertical lines), Russia’s announcement of supporting the KP in the concluding statement of the EU–Russia summit on 29 May 2002 and its actual ratification in November 2004, which triggered increased ratification activity (see kernel density estimates).\footnote{Other potential key events like the withdrawal of the U.S. in March 2001 are insignificant with respect to increased ratification activity. The same holds for the signing stage.} This indicates that a considerable number of countries ratified either after Russia’s announcement of support or after it was clear that the KP will enter into force. We, thus, build on the analysis by Fredriksson and Gaston (2000) in finding precise cut-off points. At the same time we extend their approach by distinguishing several different ratification phases.\footnote{Fredriksson and Gaston (2000) analyze the ratification process of the UNFCCC and among other approaches also use a binary response (logit) model to divide countries into abatement leaders and followers. However, the authors show that in the case of the UNFCCC there are no key events that triggered increased ratification activity.}

In the following, we first develop a simple theoretical model which explains the observations of increased ratification activity after certain key events as strategic behavior of countries with certain characteristics. Our model implies several testable hypotheses with respect to the ratification process and also predicts a relationship between the signature and the ratification stage of the KP. Second, we test these hypotheses by an empirical analysis of the signature and ratification process.

3 Theory

In line with the existing theoretical (e.g. Carraro and Siniscalco 1993, Barrett 1994, 1999 and Finus 2001) and empirical (e.g. Neumayer 2002a,b, Beron et al. 2003 and Fredriksson et al. 2007) literature, we assume that countries make rational choices in their decisions whether to sign, and whether and when to ratify the KP, i.e. countries sign/ratify if the net benefits of signing/ratification are positive. The key novelty in our approach is that we assume that the net benefits of ratification depend on whether the KP is eventually adopted. We discuss the implications of this assumption for the timing of ratification and for the relationship between ratification and signature. Furthermore, we assume that the expected net benefits of signing/ratification are a function of a vector of observable influences which we group in four different categories. Finally, we summarize the results of our theoretical considerations as testable hypotheses.
3.1 State dependent benefits of ratification

Assuming that expected benefits of the KP depend not only on countries’ ratification decisions but also on whether it will eventually enter into force, we distinguish two states of the world $S = K$ if the KP is enacted and $S = \bar{K}$ if not. Of course, whether the KP will enter into force may also depend on country $i$’s decision to ratify ($y_i = 1$) or not ($y_i = 0$).

We denote the expected benefits of country $i$ by $B_i(y_i, S)$, which depend on the country’s ratification decision $y_i$ and the state of the world $S$.

Without loss of generality, we assume that ratification has no effect on the expected benefits of all countries $i$ if the KP is not entering into force

$$B_i(1, \bar{K}) = B_i(0, \bar{K}) = B_i(\bar{K}) .$$

(1)

This allows us to characterize countries according to the signs of the following two differences:

$$\Delta B^1_i = B_i(1, K) - B_i(\bar{K}) ,$$

(2a)

$$\Delta B^2_i = B_i(1, K) - B_i(0, K) .$$

(2b)

$\Delta B^1_i > 0$ indicates that country $i$ is better off by ratifying the KP if it enters into force compared to the case that the KP will not be enacted at all. If $\Delta B^2_i > 0$, country $i$ is better off by ratifying the KP given it eventually enters into force.

Due to the two hurdles, it depends on how many and which countries ratify whether the KP enters into force. Countries for which $\Delta B^1_i > 0$ and $\Delta B^2_i > 0$ hold simultaneously – which we call class 1 countries in the following – lend unconditional support to the KP and have no incentive to postpone ratification.

Countries for which $\Delta B^1_i > 0$ but $\Delta B^2_i \leq 0$ (i.e. $B_i(0, K) \geq B_i(1, K) > B_i(\bar{K})$), which we call class 2 countries, would like the KP to enter into force, but also have an incentive to postpone ratification, as they are not worse (and probably better) off if enactment is achieved without themselves ratifying. Thus, they only have an incentive to ratify the KP if their reluctance to do so endangers its eventual adoption.

Countries for which $\Delta B^1_i \leq 0$ and $\Delta B^2_i > 0$ (i.e. $B_i(\bar{K}) \geq B_i(1, K) > B_i(0, K)$), which we call class 3 countries, prefer the KP not to enter into force at all (or are indifferent), but given the KP is enacted, they are better off ratifying. As a consequence, these countries only ratify the KP after it has already entered into force or it is foreseeable that it will do so.
Finally, there may be countries for which $\Delta B^1_i \leq 0$ and $\Delta B^2_i \leq 0$, so call class 4 countries. As these countries would never benefit from ratification, no matter whether the KP is entering into force, these countries never ratify.

### 3.2 State dependent net benefits and the timing of ratification

How can our theory of state dependent net benefits of ratification explain the observation that certain key events triggered increased ratification activity? The identification of two key events splits the ratification stage into three phases: The first phase ends with the announcement of Russia’s support for the KP on 29 May 2002 and phase three starts with its actual ratification on 4 November 2004. The second phase captures the time between these two key events.

According to our theory, class 1 countries have no incentive to postpone ratification and should, thus, do so in the first phase. For example, this may include non-Annex I countries with high potential damages from climate change like small island states.

Class 2 countries benefit from the adoption of the KP, but exhibit high compliance costs and have therefore an incentive to free-ride.\(^9\) In particular, this may hold for Annex I countries, which face binding emission targets under the KP. In addition, large countries in transition, like Brazil and China, may fall into this category, as they do not face compliance costs in the KP but may anticipate binding emission targets in subsequent treaties.\(^10\) We expect class 2 countries to ratify in the second phase. The intuition is that after the withdrawal of the U.S. the possibilities for free-riding decreased drastically. In addition, it was clear that the KP would not be enacted unless Russia ratified. Thus, Russia’s announcement of support in the concluding statement of the EU–Russia summit on 29 May 2002 can be interpreted as the consensus of the remaining Annex I countries to bring the KP into force. In fact, most Annex I countries ratified shortly after Russia announced its support.

Countries in class 3 prefer the KP not to enter into force, but if it does they are better off by ratifying. As a consequence, we expect these countries to ratify in the third phase after the KP entered into force. As an example, consider oil exporting non-Annex I countries. They prefer not to have any agreement constraining global greenhouse gas emissions. But, given the KP is enacted, they are better off ratifying in order to reap potential benefits of the KP, such as technology transfers via the clean development mechanism. In fact, all OPEC

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\(^9\) Compliance costs comprise both direct costs from investing in cleaner technologies and indirect costs by a shift of GHG intensive production into countries with less stringent environmental policies (e.g. Levinson and Taylor 2008)

\(^10\) However, after the first hurdle (55 countries) for adopting the KP was taken on 23 May 2002, these countries were not pivotal for the KP entering into force.
countries did not sign the KP during the signature period\textsuperscript{11} and ratified it after entering into force.

Our theory does not only have implications for the timing of ratification, but also implies an ordinal ordering of the three ratification phases. For countries ratifying in the first phase (class 1), the net benefits of ratification are always positive no matter whether the KP enters into force. For countries ratifying in the second phase (class 2) the net benefits of ratification are only positive if the KP would not enter into force if they would not ratify. Countries ratifying in the third phase (class 3) experience positive net benefits of ratification only given that the KP enters into force anyway, and countries not ratifying at all (class 4) are supposed to exhibit negative net benefits of ratification. Thus, the net benefits of ratifying the KP should decline with increasing ratification period.

3.3 Relationship between signature and ratification

It is not entirely clear why countries should have an incentive to sign the KP. On the one hand, if countries sign the KP but fail to ratify it afterwards, countries may fear a loss of international credibility although there are no legally binding commitments associated with signature.\textsuperscript{12} On the other hand, countries will hardly be frowned upon ratifying the KP even if they did not sign in the first place. Thus, there are some costs to signing the KP, but it is not clear what are the potential benefits.

We assume that signing the KP increases the probability that it will eventually be enacted. The idea is that if the KP receives too few signatures in the first place there is a chance that it will never reach the ratification stage but will be re-negotiated or simply dropped entirely. Thus, we assume that signing is a signal of support for the Kyoto Protocol, which is informative because it is costly.

This assumption implies that class 1 countries, which are expected to ratify the KP in the first ratification phase, should have an incentive to sign. In addition, class 3 and 4 countries, which are expected to ratify either in the third phase or never, should have no incentive to sign. The signing decision of class 2 countries which are expected to ratify in the second phase is less obvious. On the one hand, these countries would like the KP to be enacted and signing might help to achieve that. On the other hand, if there is a credibility loss from not ratifying after having signed the KP, signing might diminish the benefits from free-riding.

There is another important implication. Our theory of state dependent benefits predicts that class 3 and 4 countries, which prefer the KP not to enter into force have no incentive

\textsuperscript{11} Except Indonesia which left OPEC later on.
\textsuperscript{12} This is supported by the fact that signing but not ratifying the KP was only observed for the U.S.
to sign it. At the same time, a subgroup of these countries, i.e. class 3 countries, have an incentive to ratify the KP in the third phase. Therefore, the mere event of ratification is not necessarily a stronger signal of support than signature. Whether ratification expresses support for the KP strongly depends on the timing of ratification.

### 3.4 Observable variables

Of course, we do not directly observe a country’s expected net benefits but only whether it signs and when it ratifies the KP. However, we assume that expected net benefits are a function of a vector of observable influences, which we group into four categories: damage costs of climate change (DC), energy and emissions (EE), economic factors (EF) and political factors (PF).

**Damage costs of climate change**

An important part of the expected net benefits are the mitigated damages from climate change that affect humankind in various ways.

So far, especially the effects of climate change on agriculture (Deschênes and Greenstone 2007b, Schlenker et al. 2005) and health (Deschênes and Greenstone 2007a, 2009, Deschênes and Moretti 2009) have been analyzed in the economics literature. We use arable land per person (ARLA), value added of agricultural sector in percentage of GDP (VAAG) and precipitation per square km (PREC) as indicators to measure the influence of agricultural aspects on decision making with respect to the KP. We also include the climate change index (CCI) published by Baettig et al. (2007) that compounds information about additional extreme weather events with respect to temperature and precipitation (e.g. very hot, very dry and very wet years). As drought periods and heat waves have impacts on both agricultural output and human health, the climate change index serves as an indirect measure for potential damage costs of climate change with respect to agriculture and human health. Moreover, it also captures more general impacts on the economic system associated with extreme weather events.

Climate change may also trigger sea level rise which impacts on countries with low altitude and a high share of people living in coastal areas (Tol 2009). We include the share of population living in coastal region (CPOP) in our empirical analysis to capture effects of potential sea level rise on political decision making.

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13 The example of the small island state Tuvalu that already applied for asylum in different countries because of threatening sea level rise proofed that markedly.
Energy, emissions and economic factors

An important part of the costs of adopting the KP is the limitation of greenhouse gas emissions. Although only Annex I countries are subject to emission targets and, thus, face direct compliance costs, anticipation of compliance costs of subsequent climate change mitigation treaties by non-Annex I countries may influence their expected net benefits and, consequently, their decision whether to sign or ratify the KP.\(^{14}\) As measures for compliance costs, we include GDP per unit of energy use (GDPE) and CO\(_2\) intensity (COIN) to elicit the effect on political decision making.

Climate change will also affect energy consumption and production, as has been shown by Deschênes and Greenstone (2007a). For example, climate change may change the demand for heating in winter and air conditioning during summer. We incorporate the share of electricity production by natural gas, coal and oil (ELPR) and CO\(_2\) emissions per capita (COPC) as measures for the energy sector (Fredriksson et al. 2007).

Moreover, variations in economic factors across countries may create different incentives to join the KP. For example, Dell et al. (2008) analyze the effect of climate change on economic growth and find strong negative effects for poor countries. In addition, poor countries may be beneficiaries of financial and technological transfers due to the flexibility mechanisms incorporated in the KP and, therefore, have higher incentives to join the KP. Countries with high levels of GDP growth may expect rising greenhouse gas emission in the future and may thus have lower incentives to join the KP. In order to capture general economic patterns, we therefore include GDP per capita (GDPC) and annual GDP growth (GDPG)\(^{15}\) in our empirical analysis (Neumayer 2002a,b, Fredriksson et al. 2007).

Political Factors

Apart from damage and mitigation costs of climate change, there are other factors influencing the expected net benefits of acceding to the KP. First, Neumayer (2002a) finds that, everything else equal, democracies are more likely to ratify the KP (and three other IEAs) than non-democracies. As an indicator for the level of democracy we use the Freedom House Index on Political Rights and Civil Liberties (POLI). The hypothesis is that higher levels of political rights correlate with higher expected net benefits of IEAs.\(^{16}\)

\(^{14}\) In fact, we already observe discussions between the US and China on the role of emerging economies in the reduction efforts of greenhouse gases.

\(^{15}\) We took the 5 year average between 1994 and 1998 in order to eliminate business cycles effects.

\(^{16}\) The index ranges from 1 to 7 with 1 being highest political rights. As a consequence, expected net benefits should decrease with the level of the Freedom House Index.
Second, all countries are sovereign in their decisions whether to accede to the KP, as there exists no supranational authority which can enforce accession. Nevertheless, there exists a network of international linkages between countries. Beron et al. (2003) analyze the ratification of the Montreal Protocol in an interdependent probit model, where linkages among countries are determined by international trade flows. They find little evidence that countries are influenced by the decisions of their trade partners. Bernauer et al. (2008) study contingent behavior in a sample of 180 countries and approximately 340 IEAs over the period from 1950 to 2000. They conclude that international factors have a stronger effect on cooperative behavior than domestic factors. We use WTO membership (WTO) and trade in percentage of GDP (TRAD) as indicators for economic entanglement, and the National Material Capabilities Indicator (CINC) of the Correlates of War Project as a proxy for “power”, defined as the capacity of a state both to exercise and to resist influence (Singer et al. 1972, Singer 1988).

### 3.5 Testable hypotheses

We summarize the findings of our theoretical considerations in six hypotheses which we then test empirically. The first three testable predictions arise from our theoretical model and build the basis for the empirical setup in the next section.

Our theory predicts that countries with different levels of support for the KP select themselves into different ratification phases. This implies that in our empirical analysis the countries ratifying in the three phases should exhibit significantly different characteristics with respect to the observable variables which explain the net benefits of ratification.

(H1) Countries ratifying in the three ratification phases differ significantly with respect to the observable measures for expected net benefits of joining the KP.

Our theory also predicts that the net benefits of ratification decline with increasing ratification phase. For our empirical analysis this implies that models which account for an ordering of the underlying latent variable should be better suited than multinomial models.

(H2) There exists an ordering of the underlying latent variable for the three ratification phases.

Based on the theoretical considerations, we are able to form predictions about the relationship between signing and ratification. In fact, class 3 and 4 countries, which either sign in phase 3 or never, have no incentive to sign the KP. Thus, countries which signed the KP should have ratified it in the first or second phase and countries which ratified the KP in the third phase should not have signed it.
(H3) Countries which signed the KP ratified it in the first or second phase. Countries which ratified in the third phase did not sign the KP. The second three hypothesis are central for the influence of the determinants of signing and ratifying the KP. Hypotheses (H2) and (H3) also imply that for the signing decision other observable characteristics may turn out to be significant than for the decision when to ratify. (H4) The decisions whether to sign and when to ratify are explained by different observable characteristics.

Besides the already know determinants of joining the KP additional variables have been included and therefore allow to test for potentially omitted variables in the existing literature. (H5) Variables in all four different groups of observable characteristics influence signing and ratification of countries.

Even when controlling for observable measures of expected net benefits, we assume Annex I countries to have a significantly different adoption pattern due to their binding emission targets and their pivotal influence on the adoption of the KP. (H6) Annex I countries show a significantly different ratification pattern than the rest of countries.

4 Empirics

We test the six hypotheses by empirically analyzing the signing and ratification stage of the Kyoto Protocol (KP). After introducing the data, we outline the empirical strategy used to analyze the signing and the ratification stage. Finally, we report the results of the econometric analysis.

4.1 Data

Data for our empirical analysis stem from different sources. Table 1 shows the summary statistics and the data sources for each of the variables used in the empirical exercise. Our dataset consists of a cross-section of countries for the year 1998, the time at which the KP was open for signature. WDI is an acronym for the World Development Indicators published by the World Bank and UNFCCC denotes data from the website of the United Nations Framework Convention on Climate Change. PW is the PennWorld database provided by

17 Exceptions are: GDPG (1994–1998), CPOP (1995), CCI (based on 1961–1990 data) and PREC (Average annual precipitation in mm per m² between 1961 and 1990).
18 http://unfccc.int
the Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania (Heston et al. 2009). COW indicates that the variable is available on the Correlates of War Project website.\footnote{http://www.correlatesofwar.org/} UNEP refers to the GEO database provided by the United Nations Environment Programme\footnote{http://geodata.grid.unep.ch/} and, finally, FH denotes the variable has been downloaded from the website of the Freedom House organization.\footnote{http://www.freedomhouse.org} Samples for the signing stage and the ratification stage regression are identical except for Russia and the US that are not included in the ratification stage.\footnote{The US did not ratify the Kyoto Protocol and Russia is the pivotal player determining the thresholds for the ratification subperiods.}

Using a cross-country data set of the present form always implies some challenges with respect to the empirical strategy. In particular, there are three issues we would like to mention. First, every variable used in an econometric model may be available for a different set of countries leading to different sample sizes when using different specifications. Second, variables on country level may be highly correlated and, thus, cause a problem of collinearity in the empirical analysis. Third, there is a potential for an unobserved heterogeneity bias. We address the first issue by comparing results for different sample sizes and different sets of covariates. To avoid collinearity, we only choose variables that show a relatively low correlation.\footnote{In the present sample, the highest correlation is at -.701 for GDPC and VAAG.} However, it is not possible to construct a panel structure in order to correct for unobserved heterogeneity, as both decisions (signature and ratification) are only taken once.

4.2 Countries’ net benefits of the KP: a latent variable approach

Our assumption of rational choice implies that each country chooses, conditional on its characteristics, the combination of signing the KP, or not, and ratifying it in a certain period, which maximizes its expected net benefits. We identified two key events which splits the ratification period into three subperiods: if a country ever ratifies the KP, it may do so prior to the announcement of Russia’s ratification, after the announcement but before Russia’s actual ratification, or after Russia ratified the KP.

Then, a country is supposed to sign the KP if the underlying latent variable $y^*_s$ (its net benefit of signing) is positive. Although we do not observe $y^*_s$, we observe whether a country signed or not (i.e. whether $y_s=1$ or 0). We, therefore, hypothesize:

\begin{equation}
y_s = 1, \text{ if and only if } y^*_s > 0.
\end{equation}
Table 1: Summary statistics

| Variable | Mean | Std. Dev. | Min. | Max. | N   | Source  |
|----------|------|-----------|------|------|-----|---------|
| SIGN     | 0.437| 0.497     | 0    | 1    | 190 | UNFCCC |
| RAT      | 1.968| 0.787     | 1    | 3    | 188 |         |
| Annex 1  | 0.285| 0.405     | 0    | 1    | 190 |         |
| POLI     | 3.448| 2.228     | 1    | 7    | 183 | FI      |
| GDPE     | 4.341| 2.162     | 0.535| 10.48| 126 | WDI     |
| COPE     | 4.47 | 6.946     | 0.014| 59.392| 179|         |
| COIN     | 2.066| 0.940     | 0.153| 4.873 | 132|         |
| ARLA     | 0.254| 0.285     | 0    | 2.354| 181|         |
| GDPG     | 4.01 | 5.277     | -10.007| 39.937| 181|         |
| VAAG     | 18.508| 15.719   | 0.133| 78.643| 165|         |
| GDPC     | 7843.558| 8113.454 | 288.71| 44841.933| 180|PW      |
| TRAD     | 84.964| 44.821    | 15.865| 319.085| 180|         |
| CPF      | 0.576| 0.426     | 0    | 1.515 | 180| UNEP   |
| PREC     | 1241.011| 852.818  | 51.2 | 3566.7 | 185|         |
| WTO      | 0.717| 0.452     | 0    | 1    | 180| COW    |
| CINC     | 0.005| 0.017     | 0    | 0.148| 180|         |
| CCI      | 5.894| 2.69      | 0    | 9.48 | 188| Baettig et al. (2007) |

The reason for the max being larger than one is that overall population stems from a different source.

Furthermore, a country’s decision when to ratify the KP depends on the underlying latent variable $y^*_r$ (its expected net benefit of ratification), which in turn depends on whether the KP is entering into force. Again, we cannot observe $y^*_r$, but we observe in which period a country ratified the KP, i.e. $y_r = j$ with $j = 1, 2, 3$:

$$y_r = \begin{cases} 
\text{Period 1} & \iff \text{Mar 1998 – May 2002 }, \\
\text{Period 2} & \iff \text{May 2002 – Nov 2004 }, \\
\text{Period 3} & \iff \text{Nov 2004 – Mar 2009 }.
\end{cases} \quad (4)$$

In addition,

$$y_r = j , \quad \text{if and only if} \quad \tau_{j-1} \leq y^*_r < \tau_j , \quad (5)$$

where $\tau_k (k = 0, \ldots, 3)$ denote the threshold values for the latent variable at which a country changes the ratification period.

Then, the underlying structural model for both stages can be written as:

$$y^*_{s,r} = \alpha + \gamma DC + \delta EF + \theta EE + \eta PF + \epsilon . \quad (6)$$

where $DC$, $EF$, $EE$, and $PF$ denote the vectors of measures for damage costs of climate change, economic factors, energy and emission related factors and political variables. Furthermore, $\alpha$, $\gamma$, $\delta$, $\theta$, $\eta$, and $\epsilon$ are the parameter(s) (vectors) to be estimated and the...
disturbance term. Given the underlying latent variable approach, we use binary and ordered response models to analyze the signing and the ratification stage.

Another important issue that might play a role in our context is the potential interdependence of being an Annex I country with some other explanatory variables. For example, being an Annex I country implies compliance costs if the KP enters into force and, thus, country characteristics potentially influencing compliance costs like energy efficiency, emission levels and economic well-being may have different effects for Annex I and non-Annex I countries. Testing for potential interactions of this kind, we find no evidence for the signing stage but some evidence for the ratification stage, as discussed in more detail in Section 4.4.2.

4.3 The signing decision

The decision whether to sign the KP is a binary choice. As a consequence, we use probit type estimators to analyze the determinants of signing (or not signing) the KP:

\[
Pr(SIGN = 1 | X) = Pr(\epsilon > -X'\beta) = \Phi(X'\beta),
\]

where \(SIGN\) indicates whether a country signed the KP. \(X\) is a matrix including observations for the measures for damages costs (\(DC\)), economic factors (\(EF\)), the energy mix and emission information (\(EE\)) and political factors (\(PF\)). Furthermore, \(\beta\) and \(\epsilon\) denote the parameter vectors to be estimated and the disturbance term.

4.3.1 Model selection

In order to elicit the optimal empirical strategy in terms of model fit and predictive power, we estimated two different models using different sets of explanatory variables. We contrast the standard probit (PROB) model with the heteroscedastic probit (HETPROB), which is a generalization of the former. The reason for including a heteroscedastic model is that the variance turns out to be a function of GDP per capita (GDPC). In Table 2 we further distinguish the estimated models: First the full set of explanatory variables implying 111 observations, a reduced set of explanatory variables after applying the stepwise procedure implying also 111 observations, and a set of explanatory variables maximizing the number of observations (165 countries).

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24 Including a squared term for GDPC does not change the results.
25 We applied the stepwise procedure to detect insignificant variables (p-value > .4).
The lower part of Table 2 shows various measures of model fit for the six different specifications under consideration. Comparing both information criteria (BIC and AIC) and the percentage of correctly predicted outcomes (PCP), the standard probit and the heteroscedastic probit model with reduced sets of explanatory variables, as displayed in columns 3 and 4, are the preferred estimators.  

4.3.2 Estimation results

Marginal Effects for the determinants of signing the KP are shown in the upper part of Table 2. Although effects are robust across estimation methods and different sets of explanatory variables, we focus on the estimation results of the preferred estimators in columns 3 and 4. Although GDPC does not have a significant effect on signing itself in HETPROB, it turns out that the likelihood-ratio test of heteroscedasticity is significant with a p-value of 0.057.

The effects of ARLA, PREC, and COIN are positive and highly significant with semi-elasticities of roughly .09, .24, and .22. For HETPROB, we also find a positive and significant effect for CCI (.27) and for PROB an effect for the Annex I dummy (.043). Moreover, all models show evidence for a significant positive effect of the measure of political power (CINC) with semi-elasticities of .02. In addition, we find negative and statistically significant effects for VAAG and ELPR with −.17 for VAAG and between −.002 and −.14 for ELPR, respectively. GDPE shows a negative effect for PROB with −.23 but it slightly fails significance at the 10% level for HETPROB.

Although VAAG and ARLA should both reflect damages on agriculture, they exhibit opposite signs. A closer look at the data reveals that high values of VAAG do not imply high values in ARLA and vice versa. In fact, primarily poor countries exhibit high values of VAAG, such as Liberia, Guinea-Bissau, etc. In contrast, Australia and Canada are among the top five countries with respect to ARLA. Thus, the opposite signs may reflect that countries with a high share of agricultural value added in GDP may experience different effects from climate change than countries with a high density of arable land. Moreover, rising temperatures may have different effects on agriculture in the northern and southern hemisphere in terms of adaptation opportunities and agricultural output.

Comparing our results across the specifications displayed in Table 2, it is evident that our findings are robust to the choice of estimator, covariates and sample size.

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26 We also estimated both models using different sets of explanatory variables while holding the number of observations constant. Results for these specifications are available upon request.
## Table 2: Signing Stage Results

|     | (1) PROB | (2) HETPROB | (3) PROB | (4) HETPROB | (5) PROB | (6) HETPROB |
|-----|----------|-------------|----------|-------------|----------|-------------|
| ARLA| 0.104    | 0.102       | 0.0977   | 0.0906      | 0.109    | 0.105       |
|     | (0.027)  | (0.003)     | (0.040)  | (0.030)     | (0.001)  | (0.000)     |
| VAAG| -0.156   | -0.189      | -0.165   | -0.207      | -0.108   | -0.129      |
|     | (0.006)  | (0.003)     | (0.005)  | (0.004)     | (0.001)  | (0.000)     |
| PREC| 0.222    | 0.184       | 0.246    | 0.241       | 0.127    | 0.147       |
|     | (0.002)  | (0.006)     | (0.000)  | (0.000)     | (0.005)  | (0.033)     |
| CCI | 0.167    | 0.168       | 0.195    | 0.272       | -0.108   | -0.129      |
|     | (0.399)  | (0.167)     | (0.319)  | (0.041)     | (0.199)  | (0.167)     |
| GDPC| 0.0758   | -0.0169     | 0.0916   | 0.0434      | 0.0528   | 0.0863      |
|     | (0.267)  | (0.804)     | (0.173)  | (0.618)     | (0.273)  | (0.197)     |
| GDPE| -0.223   | -0.129      | -0.228   | -0.169      | -0.0818  | -0.000296   |
|     | (0.031)  | (0.168)     | (0.018)  | (0.101)     | (0.245)  | (0.997)     |
| COIN| 0.252    | 0.179       | 0.249    | 0.215       | 0.254    | 0.197       |
|     | (0.053)  | (0.148)     | (0.030)  | (0.079)     | (0.030)  | (0.079)     |
| COPC| -0.0577  | -0.0101     | -0.0580  | -0.0240     | -0.0108  | -0.0233     |
|     | (0.158)  | (0.790)     | (0.109)  | (0.470)     | (0.638)  | (0.428)     |
| CINC| 0.0196   | 0.0305      | 0.0164   | 0.0242      | 0.0235   | 0.0221      |
|     | (0.045)  | (0.002)     | (0.053)  | (0.014)     | (0.000)  | (0.000)     |
| TRAD| -0.0818  | 0.0114      | -0.0916  | -0.0226     | 0.00351  | -0.000296   |
|     | (0.245)  | (0.762)     | (0.182)  | (0.435)     | (0.962)  | (0.997)     |
| GDPG| -0.00197 | -0.0122     | -0.0347  | -0.00906    | -0.0146  | -0.00187    |
|     | (0.640)  | (0.488)     | (0.143)  | (0.159)     | (0.062)  | (0.089)     |
| ELPR| -0.146   | -0.00191    | -0.136   | -0.00187    | -0.0074  | -0.0108     |
|     | (0.062)  | (0.017)     | (0.073)  | (0.089)     | (0.017)  | (0.089)     |
| POLI| -0.0107  | -0.0174     | -0.0747  | -0.0108     | -0.0174  | -0.0107     |
|     | (0.887)  | (0.356)     | (0.196)  | (0.653)     | (0.356)  | (0.653)     |
| WTO | 0.0190   | 0.0160      | 0.0815   | 0.101       | 0.0190   | 0.0160      |
|     | (0.815)  | (0.883)     | (0.186)  | (0.183)     | (0.815)  | (0.883)     |
| Annexe I| 0.0438 | 0.0992     | 0.0428   | 0.131       | 0.0412   | 0.328       |
|     | (0.050)  | (0.325)     | (0.034)  | (0.174)     | (0.004)  | (0.011)     |

|     | 111      | 111        | 111      | 111         | 165      | 165         |
| N   |          |            |          |             |          |             |
| LL0 | -76.90   | -76.90     | -113.7   | -82.96      | -78.54   | -78.16      |
| LL  | -43.69   | -40.73     | -43.98   | -42.13      | -78.54   | -78.16      |
| BIC | 167.4    | 166.2      | 149.2    | 150.2       | 223.5    | 227.8       |
| AIC | 121.4    | 117.5      | 114.0    | 112.3       | 183.1    | 184.3       |
| HL(p)| (0.2173) | (0.2194)   | (0.2879) |             |          |             |
| PCP | 82.88    | 83.78      | 82.88    | 81.98       | 75.76    | 77.58       |

Note: Parameter estimates show semi-elasticities for the variables in the upper part and marginal effects (discrete changes for dummy variables from 0 to 1) in the lower part; p-values in parentheses. Standard errors are robust. N, number of observations; LL0, constant-only Log-Lik.; LL, Log-Lik.; BIC, Bayesian Information Criterion; AIC, Akaike’s Information Criterion; HL, Hosmer-Lemeshow goodness-of-fit test; PCP, percent correctly predicted outcomes.
4.4 The ratification decision

In contrast to signing, all parties to the UNFCCC included in our data set, except for the USA, ratified the KP until the end of 2009. Thus, the question is not whether a country ratified but rather when. As already mentioned, we split the ratification period into three subperiods: (i) before Russia announced ratification, (ii) after Russia’s announcement and its actual ratification (which triggered the KP to enter into force), or (iii) after Russia’s ratification and the KP becoming effective. According to hypothesis (H2), the underlying latent variable, the expected net benefits of ratification, is decreases with later ratification phases. We model the ratification stage as an ordered response assuming that:

\[ Pr(RAT = j | X) = F(\tau_j - X'\beta) - F(\tau_{j-1} - X'\beta) , \]  

where \( F \) indicates the cumulative distribution function of the error term \( \epsilon \), \( \beta \) is the parameter vector and \( \tau_1 \) to \( \tau_{j-1} \) denote threshold parameters to be estimated assuming that \( \tau_0 = -\infty \) and \( \tau_3 = \infty \).

As shown in the following section, the standard ordered response model is too restrictive in this setting. As a consequence, we check different alternatives in order to decide on the best estimator. It turns out that a generalized ordered response model (Maddala 1986, Peterson and Harrell 1990) with the logistic cumulative density function as link function \( F \), which allows (some of) the parameter estimates to differ between outcomes \( j \), performs best in terms of model fit:

\[ Pr(RAT = j | X) = F(\tau_j - X'\beta_j) - F(\tau_{j-1} - X'\beta_{j-1}) \]  

4.4.1 Model selection

Two important questions have to be discussed at this stage. First, is hypothesis (H1) concerning the classification of the dependent variable \( y_r \) supported by the data? In contrast to the signing stage, we do not model ratification as a binary decision. Instead, by splitting the ratification period into three subperiods, we use a more subtle measure that has to be validated by the data. More precisely, it may be that the key events we identified are not as important as we presume and, thus, our set of explanatory variables is not able to distinguish between outcomes (Anderson 1984). Second, is hypothesis (H2) about the ordering of our dependent variable that is implied by our underlying latent variable backed by the empirical model? On the one hand, if the outcome categories were different, but there was no ordering, unordered models were preferable, as they are less restrictive compared to or-
Table 3: Test for Combining Alternatives

|                | Full, N = 109 | Stepwise, N = 112 | Max. Observation, N = 163 |
|----------------|--------------|------------------|---------------------------|
|                | Alt. tested  |  |                |
|                | chi2    | df | P>chi2 | Alt. tested  | chi2    | df | P>chi2 | Alt. tested  | chi2    | df | P>chi2 |
| 2 ↔ 3          | 48.715   | 16 | 0.000   | 2 ↔ 3          | 37.647   | 11 | 0.000   | 2 ↔ 3          | 56.133   | 11 | 0.000   |
| 2 ↔ 1          | 26.644   | 16 | 0.046   | 2 ↔ 1          | 23.552   | 11 | 0.015   | 2 ↔ 1          | 22.687   | 11 | 0.020   |
| 3 ↔ 1          | 38.528   | 16 | 0.001   | 3 ↔ 1          | 30.790   | 11 | 0.001   | 3 ↔ 1          | 24.158   | 11 | 0.012   |

dered models. If, on the other hand, there were an underlying ordering, multinomial models were inefficient, as they do not utilize all available information.

To test the validity of the classification of the dependent variable, we use a Wald test (after estimating a multinomial logit) to detect whether our different alternatives can be combined. Full, Stepwise, and Max. Observation indicate the set of covariates and resulting sample size with the full set of explanatory variables, a reduced set after applying the stepwise procedure, and a reduced set that implies the maximum number of observations, respectively. According to the results shown in Table 3, we find clear evidence in all our specifications that we can reject the Null-hypothesis that all parameter estimates for a given pair of alternatives are zero.

The second question boils down to the estimator choice. Candidates are either one of the two polar types of standard multinomial and ordered models or a model type lying in between. As we shall show, the generalized ordered logit (Maddala 1986, Ierza 1985), in particular the partial proportional odds model (Peterson and Harrell 1990), serves best in terms of model fit. Table 4 shows the estimation results for our set-up using different estimation approaches.

In general, multinomial models are more flexible than standard ordered response models. This comes, however, at the expense of an efficiency loss, as the number of estimated parameters increases drastically. However, estimating a standard ordered response model may be too restrictive (Boes and Winkelmann 2006) for the following reasons. First, the parallel lines assumption may be violated implying there exists evidence against the restriction of identical estimates for all alternatives. As a Brant test applied after an ordered logit supports this hypothesis for several variables, stratified (Anderson 1984), sequential or generalized ordered models (Maddala 1986) are advisable. Second, there may be heteroscedasticity in our model, which is supported by our previous findings on the signature stage. Thus,

27 The tests has been calculated using the mlogtest command (user written by Long and Freese 2005) in Stata.
28 We sequentially detected the most insignificant variables (p-value > .4) and skipped them from the final estimation.
29 User written by Long and Freese 2005.
a generalization of the traditional ordered logit/probit (Alvarez and Brehm 1995) may be appropriate.

### Table 4: Ratification Stage Model Fit

|               | MLOG | OLOG | SLOG | SEQL | GOLOG |
|---------------|------|------|------|------|-------|
| N             | 109  | 109  | 109  | 109  | 109   |
| LL0           | -113.6 | -113.6 | -113.6 | -113.6 | -113.6 |
| LL            | -64.46 | -85.86 | -83.70 | -65.43 | -79.99 |
| BIC           | 288.4  | 256.2  | 256.5  | 290.4  | 249.1  |
| AIC           | 196.9  | 207.7  | 205.4  | 198.9  | 198.0  |
| LR(p)         |       |       |       |       | 0.0000134 |
| PCP           | 69.72  | 66.06  | 66.97  | 71.56  | 67.89  |

|               | Stepwise |      |      |      |       |
|---------------|----------|------|------|------|-------|
| N             | 112      | 112  | 112  | 112  | 112   |
| LL0           | -116.3   | -116.3 | -116.3 | -116.3 | -116.3 |
| LL            | -74.07   | -91.49 | -89.01 | -74.29 | -80.26 |
| BIC           | 261.4    | 244.3  | 244.1  | 261.8  | 231.3  |
| AIC           | 190.5    | 209.0  | 206.0  | 196.6  | 190.5  |
| LR(p)         |       |       |       |       | 0.0000134 |
| PCP           | 75       | 63.39  | 65.18  | 69.64  | 68.75  |

|               | Max. Observations |      |      |      |       |
|---------------|-------------------|------|------|------|-------|
| N             | 163               | 163  | 163  | 163  | 163   |
| LL0           | -176.2             | -176.2 | -176.2 | -176.2 | -176.2 |
| LL            | -140.2             | -159.6 | -150.2 | -139.4 | -144.6 |
| BIC           | 402.6              | 385.5  | 371.8  | 401.1  | 365.6  |
| AIC           | 328.4              | 345.3  | 328.5  | 326.9  | 319.2  |
| LR(p)         |       |       |       |       | 0.000000297 |
| PCP           | 55.83              | 53.99  | 48.47  | 57.06  | 60.12  |

Note: N, number of observations; LL0, constant-only Log-Lik.; LL, Log-Lik.; BIC, Bayesian Information Criterion; AIC, Akaike’s Information Criterion; LR(p), p-value for Lik. ratio test (olog nested in golog); PCP, percent correctly predicted outcomes. The user written commands gologit2 (Williams 2006) have been used to estimate the generalized ordered model.

In order to find the preferable empirical model, we estimate several model specifications and list important measures of fit in Table 4. Columns 1 and 2 show the results for the multinomial logit model (MLOG) and the standard ordered logit (OLOG). Results for the the stratified logit (SLOG) model and the sequential logit (SEQL) are stated in columns 3 and 4. Finally, column 5 shows the result for the preferred generalized ordered logit model (GOLOG).30

Comparing both information criteria for the multinomial logit (MLOG) and the ordered logit (OLOG) estimates for all three specifications, there is no clear indication which to prefer. While BIC is in favor of the OLOG, the values for AIC support the MLOG results. The percentage of correctly predicted outcomes (PCP), however, lends further support for the MLOG model. However, both estimates are inferior to the GOLOG results in column 5. The stratified logit model (SLOG), as introduced by Anderson (1984), relaxes the parallel

30 In addition, we also used a heteroscedastic ordered model as suggested by (Williams 2009). However, as the Log-likelihood function did not converge, we were not able to calculate meaningful marginal effects.
regression assumption and is applicable in case of doubt for an ordering of the dependent variable. Comparing all available measures of fit, the stratified logit model does not outperform most of the other model specifications, and in particular, not the preferred generalized ordered logit model in column 5.

Another attractive approach in our setting is the sequential logit model (SEQL), as proposed by Maddala (1986). The appealing feature of sequential models is their ability to explicitly account for the time dimension of the dependent variable. However, comparing AIC and BIC, also SEQL is outperformed by GOLOG. SEQL only outperforms GOLOG in terms of predictive power. However, the difference is always in a reasonable range in order to stick to GOLOG as the difference in AIC and BIC usually is rather substantial.

Finally, column 5 displays results for the preferred generalized ordered logit/partial proportional odds model (GOLOG). In order to calculate and interpret marginal effect we therefore rely on these estimates, as they are best in terms of information criteria and at the same time show a reasonable predictive power (PCP = 70%) for the preferred stepwise specification.

4.4.2 Estimation results

Table 5 shows the estimation results for the ratification stage. We present estimates for the preferred estimator, the generalized ordered logit model (GOLOG), with the full set of explanatory variables (N = 109), after applying the stepwise procedure (N = 112) and with the maximum number of observations (N = 163). Although information criteria and predictive power reject the first and third specification (while holding the number of observations fixed), we provide the results in order to compare marginal effects for all sample sizes and sets of covariates. The results show very small differences and even less so for the significant effects. In addition, Table 6 presents marginal effects when including an interaction term for GDPE and Annex I membership. We tested for several interactions including our measures for emissions, energy efficiency, and economic well-being and for the Stepwise and the Max. Observations samples. Using an iterative process and only testing for one interaction at a time, we found several interaction effects (see Table 7 in the appendix). However, including all candidate interaction at once leads to only one significant interaction term which is the interdependence of Annex I membership and GDPE. In Table 6 we therefore display the results for our preferred estimator and sample including the interaction on GDPE and Annex I membership.

31 We estimate the sequential model using the user written command seqlogit in Stata by Buis (2007).
When interpreting the results we stick to the estimation including the interaction term as both AIC and BIC are smaller in this case (Table 6). Comparing results with (Table 6) and without (Table 5) interaction terms, we observe that results are highly consistent between the two model specifications. For the latter specification, covariates are tending to be more significant.

We find that countries with a higher VAAG did have a significantly higher probability of ratifying in the first period (.07) and a significantly lower probability in the third period (−.12). The same holds for GDPC (.12 and −.12, respectively). That is, ceteris paribus, a higher level of GDP per capita increases (decreases) the probability of ratifying in period one (three) by .12 (−.22). Also the results on COPC are intuitive: a higher level of CO₂ per capita reduces (increases) the probability of signing in period one (three) by −.09 (.16). ELPR shows a similar pattern with a significant positive effect on period one and a negative effect on period three (.001 and −.002). Also political factors impact on the timing of ratification. Countries with higher levels of CINC are less likely to ratify in the first period and are more likely to ratify in period two (−.05 and 0.07). In addition, everything else equal, the degree of political rights have a significant positive effect on ratification in the first period (−.05) and a negative effect on the probability of ratification in period three (0.10), while being member of the WTO is at the margin of significance for period one (.06 with p-value of 0.10). Trade openness (TRAD) exerts a significant positive impact on period three (.11).

Effects for GDP of unit energy use (GDPE) and Annex I membership (controlling for the interaction) are given in the right part of Table 6. Controlling for the interaction with GDPE, the probability of ratifying in period one (two) is 0.25 (0.27) lower (higher) for Annex I countries. However, effects for GDPE when controlling for Annex I membership are not statistically significant.

In order to test for hypothesis (H3) about the relationship between signing and the timing of ratification, we also did a reduced form regression where we used the predicted probabilities of the signing stage to explain ratification behavior. We find that a higher probability of signing increases the likelihood of ratifying in period one (not significant) and two (highly significant), and reduces the likelihood of ratifying in period three (highly significant), which confirms hypothesis (H3).

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52 We also ran all potential model specifications, as described in Section 4.4.1 and summarized in Table 4, with and without interaction terms. Among all possible variations, the model specification presented in Table 6 is preferable with respect to the AIC and BIC information criteria.
Table 5: Ratification Stage Estimation Results

| Period | Full | | | Stepwise | | | Max. Observations | | |
|--------|------|------|------|---------|------|------|-------------|------|------|
|        | 1    | 2    | 3    |         | 1    | 2    | 3           |         |       |
| ARLA   | 0.0381 | -0.00386 | -0.0343 |         | -0.0138 | -0.00239 | 0.0162 |         |       |
|        | (0.421) | (0.727) | (0.455) |         | (0.661) | (0.693) | (0.659) |         |       |
| VAAG   | 0.0386 | -0.00390 | -0.0347 |         | 0.0546 | 0.0228 | -0.0774 |         |       |
|        | (0.491) | (0.758) | (0.496) |         | (0.177) | (0.405) | (0.169) |         |       |
| PREC   | 0.122 | -0.0124 | -0.110 |         |         |         |         | 0.0536 | 0.00930 | -0.0629 |
|        | (0.028) | (0.732) | (0.054) |         |         |         |         | (0.288) | (0.528) | (0.292) |
| CCI    | -0.118 | 0.0120 | 0.106 |         |         |         |         |         |         |         |
|        | (0.648) | (0.769) | (0.656) |         |         |         |         | (0.966) | (0.965) | (0.965) |
| GDPC   | 0.0820 | -0.00830 | -0.0737 | 0.0876 | 0.0366 | -0.124 |         | 0.0663 | 0.0115 | -0.0778 |
|        | (0.340) | (0.723) | (0.385) |         | (0.151) | (0.449) | (0.187) |         | (0.187) | (0.546) | (0.222) |
| GDPE   | -0.157 | 0.0158 | 0.141 |         | -0.0896 | -0.0375 | 0.127 |         |         |         |
|        | (0.196) | (0.746) | (0.195) |         | (0.263) | (0.379) | (0.218) |         |         |         |
| COIN   | 0.194 | -0.0196 | -0.174 | 0.0752 | 0.0314 | -0.107 |         |         |         |         |
|        | (0.081) | (0.725) | (0.137) |         | (0.304) | (0.399) | (0.263) |         |         |         |
| COPC   | -0.146 | 0.0148 | 0.131 | -0.0906 | -0.0379 | 0.129 |         | -0.0600 | -0.0104 | 0.0704 |
|        | (0.213) | (0.720) | (0.276) |         | (0.065) | (0.389) | (0.077) |         | (0.094) | (0.483) | (0.105) |
| CINC   | -0.0118 | 0.00119 | 0.0106 | -0.0690 | 0.0830 | -0.0141 |         | -0.0661 | 0.0805 | -0.0144 |
|        | (0.654) | (0.784) | (0.656) |         | (0.027) | (0.008) | (0.249) |         | (0.037) | (0.012) | (0.131) |
| TRAD   | -0.120 | 0.0122 | 0.108 | -0.0598 | -0.0250 | 0.0848 |         | -0.0407 | -0.00706 | 0.0478 |
|        | (0.118) | (0.745) | (0.108) |         | (0.239) | (0.345) | (0.180) |         | (0.552) | (0.616) | (0.531) |
| CPOP   | -0.0396 | 0.00401 | 0.0356 |         |         |         | -0.0937 | -0.0162 | 0.110 |
|        | (0.718) | (0.816) | (0.714) |         |         |         | (0.328) | (0.547) | (0.334) |         |
| GDPG   | 0.0000470 | -0.00000475 | -0.0000422 | 0.00132 | 0.000550 | -0.00187 |         | -0.00129 | -0.000224 | 0.00152 |
|        | (0.997) | (0.997) | (0.997) |         | (0.810) | (0.809) | (0.808) |         | (0.810) | (0.809) | (0.808) |
| ELPR   | 0.00163 | -0.000165 | -0.00147 | 0.00132 | 0.000550 | -0.00187 |         |         |         |         |
|        | (0.176) | (0.745) | (0.175) |         | (0.088) | (0.372) | (0.081) |         |         |         |
| POLI   | -0.0595 | -0.0672 | 0.127 | -0.0728 | -0.0305 | 0.103 |         | -0.0563 | -0.00975 | 0.0660 |
|        | (0.019) | (0.035) | (0.000) |         | (0.002) | (0.313) | (0.000) |         | (0.001) | (0.434) | (0.001) |
| WTO    | 0.0761 | 0.00614 | -0.0822 | 0.0801 | 0.0695 | -0.150 |         |         |         |         |
|        | (0.317) | (0.856) | (0.406) |         | (0.142) | (0.303) | (0.174) |         |         |         |
| Annex I | -0.164 | -0.0488 | 0.213 | -0.222 | 0.254 | -0.0321 |         | -0.254 | 0.342 | -0.0885 |
|        | (0.053) | (0.496) | (0.105) |         | (0.009) | (0.033) | (0.807) |         | (0.000) | (0.001) | (0.430) |
| N      | 109 | | | 112 | | | 163 | | |
| SE     | | | | | | | | | |
| LL0    | -113.6 | | | -116.3 | | | -176.2 | | |
| LL     | -79.99 | | | -80.26 | | | -144.6 | | |
| BIC    | 249.1 | | | 231.3 | | | 365.6 | | |
| AIC    | 198.0 | | | 190.5 | | | 319.2 | | |
| PCP    | 67.89 | | | 68.75 | | | 60.12 | | |

Note: Parameter estimates show semi-elasticities for the variables in the upper part and marginal effects (discrete changes for dummy variables from 0 to 1) in the lower part; p-values in parentheses; Estimates have been obtained by running the gologit2 command (user written by Williams (2006)) in Stata 11 with robust standard errors. The autofit command has been applied to determine the variables for which the parallel lines assumption can be imposed. A Wald test implied parallel lines in the preferred specification for all variables except CINC, TRAD and Annex I. Results are robust to different sensitivity checks like, e.g., dropping Annex I countries or OPEC members.
Table 6: Ratification Stage Estimation Results with Interaction

| Period | Stepwise |     |     |     |
|--------|----------|-----|-----|-----|
|        |          | 1   | 2   | 3   |
| VAAG   | 0.0652   | 0.0547 | -0.120 | (0.081) | (0.208) | (0.058) |
| GDPC   | 0.121    | 0.101 | -0.222 | (0.014) | (0.213) | (0.024) |
| COIN   | 0.0705   | 0.0591 | -0.130 | (0.204) | (0.264) | (0.164) |
| COPC   | -0.0856  | -0.0717 | 0.157 | (0.058) | (0.252) | (0.073) |
| CINC   | -0.0535  | 0.0685 | -0.0150 | (0.038) | (0.010) | (0.205) |
| TRAD   | -0.0598  | -0.0501 | 0.110 | (0.139) | (0.184) | (0.076) |
| ELPR   | 0.00132  | 0.00111 | -0.00242 | (0.067) | (0.186) | (0.039) |
| POLI   | -0.0553  | -0.0463 | 0.102 | (0.011) | (0.116) | (0.000) |
| WTO    | 0.0646   | 0.0989 | -0.164 | (0.100) | (0.214) | (0.124) |
|        |          |     |     |     |

| Period | Stepwise |     |     |     |
|--------|----------|-----|-----|-----|
|        |          | 1   | 2   | 3   |
| Annex I| -0.251   | 0.269 | -0.0182 | (0.0033) | (0.010) | (0.859) |
| GDPE (non Annex I) | -0.000759 | 0.000291 | 0.000557 | (0.558) | (0.674) | (0.568) |
| GDPE (Annex I) | -0.0000335 | -0.000475 | 0.000508 | (0.592) | (0.601) | (0.595) |

Note: Marginal Effects including an interaction term for GDPE and Annex I. Parameter estimates show semi-elasticities for the variables in the upper part and marginal effects (discrete changes for dummy variables from 0 to 1) in the lower part; p-values in parentheses; Estimates have been obtained by running the gologit2 command (user written by Williams (2006)) in Stata 11 with robust standard errors. The autofit command has been applied to determine the variables for which the parallel lines assumption can be imposed. The right part of the table displays probability changes (Annex I) and elasticities (GDPE) for Annex I and GDPE given the interaction of both. Effects and corresponding p-values have been generated using the prvalue command developed by Long and Freese (2005) in Stata 11.

5 Discussion

To explain the observation that the ratification stage of the KP splits into three phases, we developed a theory of state dependent net benefits of ratification which grouped countries into 4 different classes. While class 1 countries should ratify in the first phase and class 4 countries should never ratify, class 2 and 3 countries are prone to strategic behavior: Class 2 countries should only ratify if their reluctance endangers the adoption of the KP (second phase) and class 3 countries only after the KP entered into force (third phase).

Our empirical analysis strongly supports our theoretical considerations summarized in hypotheses (H1)–(H6). The division of the ratification period into three subperiods according to the two key events of Russia’s ratification announcement and its actual ratification (which, in turn, triggered the KP to enter into force), proofs to be appropriate. As shown in Table 3, the three subperiods are significantly different which confirms hypothesis (H1). Our search for the most appropriate estimator (see Table 4) gives strong support for the generalized ordered logit model implying that there exists an ordering of the underlying latent variable,
the expected net benefits of ratification, with respect to the three ratification phases. In line with hypothesis (H2), the expected net benefits of ratification decrease with later ratification phases. We also find support for hypothesis (H3) that countries which signed the KP are more likely to ratify in the first (non-significant) and second ratification phase (highly significant) and are less likely to ratify in the third (highly significant).

For the decision whether to sign the KP we find support for hypothesis (H5) that a broad selection of measures – covering damage and compliance cost measures, energy measures and political factors – turn out to be important, some of which have not yet been discussed in the literature. Countries are more likely to sign, the higher is the share of arable land (ARLA), precipitation (PREC), the climate change index (CCI), the CO₂ intensity (COIN), the power index (CINC). In addition, the probability to sign is smaller, the lower is the value added of agricultural sector in percentage of GDP (VAAG), GDP per unit of energy use (GDPE) and the share of electricity production from fossil fuel sources (ELPR). With respect to other studies analyzing the signing stage of the KP, we cannot confirm the positive effect of democracy and GDP as found by Neumayer (2002a) and Neumayer (2002b) which may be covered by other variables like the power measure or the dummy for Annex I. We confirm, however, that trade openness plays no role for signing (Neumayer 2002b).

Also the decision when to ratify is governed by a wide array of influences covering all four groups of indicators, thereby supporting hypothesis (H5). In line with hypothesis (H4), the significant covariates for the ratification decision do not always match the ones for signing. In fact, indicators for damage costs of climate change seem to have a lower and political factors a higher predictive capability for the decision when to ratify the KP. Value added of agricultural sector in percentage of GDP (VAAG), GDP per capita (GDPC) and the share of electricity production from fossil fuel sources (ELPR) have a significantly positive impact in the first ratification phase and a significantly negative effect in the third. Contrariwise, CO₂ emissions per capita (COPC) and the Freedom House index for political rights (POLI) have a significantly negative impact on ratification in the first and significantly positive impact for ratification in the third period. The power index (CINC) exerts a significantly negative effect on periods one and three and a significantly positive effect on period two. Controlling for the interaction between Annex I membership and GDP per unit of energy use

33 Comparing signing and ratification results, we find that both VAAG and ELPR exert a negative effect on signing but a positive effect on ratification in the first period, which is puzzling as, according to our theory, countries which ratify in the first period should also have an incentive to sign the KP. Looking into the data reveals that this result is driven by several very poor countries like Uganda, Malawi, Gambia, Nauru, Guinea, and Equatorial Guinea all of which have high levels of VAAG, low levels of ELPR, did not sign the KP but ratified in the first period. These countries should be unconditional beneficiaries of the KP, as they will be negatively affected by climate change but will probably not face any binding emission regulations in the foreseeable future. In line with our theory, they ratified in the first period. However, we do not know why these countries did not sign the KP in the first place.
(GDPE), Annex I countries are less (more) likely to ratify in period one (two). Finally, trade as percentage of GDP (TRAD) exerts a significantly positive impact on ratification in the third period. Overall, it seems that less influential countries with pronounced agricultural sector (high share of agricultural sector on GDP, low CO\textsubscript{2} emissions per capita, low power index, non-Annex I country) were significantly more likely to ratify in the first subperiod, developed and powerful countries (Annex I country, high power index) were more likely to ratify in the second and less influential and less democratic countries with high CO\textsubscript{2} emissions per capita and low share of agricultural sector on GDP ratified in the third subperiod. In line with the theory on international environmental agreements and in contrast to previous findings for other international agreements (Beron et al. 2003), we find some evidence for countries being aware of free-riding opportunities. In addition, we confirm the importance of political factors for the ratification process (Fredriksson et al. 2007) and add evidence for a wide range of economic measures.

Finally, we do also find clear evidence for hypothesis (H6). Annex I membership does not only exert a significantly positive impact on signing, but also on ratification in period two while holding all other measures constant. Thus, Annex I countries did behave as predicted: ratification has been postponed until free-riding opportunities ceased to exist.

In summary, the empirical analysis provides sound empirical evidence for strategic behavior with respect to ratifying the KP. On the one hand, class 3 countries are only expected to ratify if the KP cannot be prevented and, therefore, have no incentive to sign the KP in the first place. As already argued, this is certainly true for OPEC members and other major oil exporting countries which mostly did not sign and ratified in phase 3. On the other hand, Annex I countries, which have a strong incentive to free-ride on the emission reductions of other Annex I countries, were reluctant to ratify the KP right away but ratified in phase two. Nevertheless, in general, they showed support for the KP by signing it in the first place.\textsuperscript{34} The 55\% emission hurdle in combination with the U.S.' withdrawal from the KP and the resulting pivotal role of Russia reduced free-riding opportunities substantially which eventually led to a cooperation of the remaining Annex I countries in bringing the KP into power.

With hindsight it seems that the 55\% emission hurdle helped to overcome Annex I countries’ reluctance to ratify the KP. However, we are cautious to suggest that such hurdles are, in general, helpful to overcome free-riding incentives in the context of international environmental agreements. On the one hand, they may help to coordinate on cooperative actions, as in the case of the KP. On the other hand, the higher is the hurdle, the higher is

\textsuperscript{34} Also countries with high power index were more likely to sign and, at the same time, less likely to ratify in the first ratification period.
the negotiation power of individual countries to exert side-payments and transfers for their cooperation, which may actually impede cooperation (see, for example, the COP 15 meeting in Copenhagen). Nevertheless, we consider further empirical investigation of similar rules in international agreements as a fruitful avenue for further research.

6 Conclusion

We studied strategic behavior with respect to joining the Kyoto Protocol (KP). To this end we developed a simple theory of state dependent net benefits of ratification and test it empirically. For the particular design of the KP, our theory predicts discontinuous effects in the adoption process that have not been analyzed so far. In fact, we find that, conditional on their specific characteristics, countries select themselves into three ratification phases. We also provide an explanation why almost all countries ratified the KP but only less than half of them signed it in the first place. Finally, we identify additional key determinants of countries’ behavior on both stages that refine existing findings.
Appendix

Table 7: Interaction effects for Stepwise and Max. Observations

|            | Stepwise | Max. Observations |
|------------|----------|-------------------|
|            | GDPC     | GDPE   | COPC  | TRAD | GDPC    | COPC  | TRAD |
| N          | 112      | 112    | 112   | 112  | 163     | 163   | 163  |
| Period 1   | -0.238   | -0.251 | -0.241| -0.225| -0.251  | -0.257| -0.266|
| p-value    | 0.00142  | 0.00351| 0.00232| 0.0184| 0.000376| 0.0000664| 0.000119|
| Period 2   | 0.274    | 0.269  | 0.244 | 0.193| 0.351    | 0.323 | 0.315|
| p-value    | 0.00373  | 0.0103 | 0.0402| 0.115| 0.00133  | 0.0228| 0.00810|
| Period 3   | -0.0362  | -0.0182| -0.00347| 0.0317| -0.101  | -0.0660| -0.0489|
| p-value    | 0.749    | 0.859  | 0.980  | 0.795| 0.426    | 0.674  | 0.691|

Note: As GDPE is not available in the sample with Max. Observations and in order to check for robustness, we estimated the preferred specification (Stepwise) and Max. Observations including one interaction term at a time. Results are extremely robust with only little deviations for TRAD.

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