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FACULTY OF SOCIAL SCIENCES

Institute of Political Studies

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Collective action problem in international climate governance

Bachelor's Thesis

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Declaration

1. I hereby declare that I have compiled this thesis using the listed literature and resources only.
2. I hereby declare that my thesis has not been used to gain any other academic title.
3. I fully agree to my work being used for study and scientific purposes.

In Prague on the 3rd of May Nathanael Illies

Reference

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Abstract

This thesis addresses the collective action problem in international climate governance and explores approaches to mitigate the problem and promote climate cooperation. Methodologically, game-theoretic models are used to represent the climate governance of China, the USA, India, and the EU and to analyse these global players regarding potential collective action problems. First, it is found that all players have different crucial factors that determine their climate policies. These factors include economic and geopolitical competitiveness, domestic polarisation about climate action, high vulnerability towards climate risks and different evaluations about abatement efforts. Secondly, these factors result in potential collective action problems that are specific to each country and entail a sub-optimal provision of the collective good of emissions abatement and a lack of climate cooperation. Thirdly, distinct solutions for mitigating the collective action problem and promoting collective climate action are explored. By doing so, the thesis finds that further examining individual countries' climate strategies is essential for finding comprehensive solutions to enhance global climate cooperation in the long run.

Keywords

Collective action problem, international climate governance, game theory, free-riding, emissions abatement, US, China, India, EU

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1 Introduction

1.1 The collective action problem in international climate governance

Half a century ago, the *Club of Rome* sparked a global discussion about resource depletion and environmental protection with its report “The Limits to Growth” (Meadows et al., 1972). Subsequently, environmental and climate action has gained widespread attention and resulted in the formation of international climate regimes such as the Paris Agreement from 2015 or climate cooperation, for instance, through the Emissions Trading System of the European Union.
However, efforts to combat climate change and protect the environment are frequently undermined by the so-called collective action problem. Mancur Olson first identified it in his salient work “The Logic of Collective Action”:

> *“Any group or organization, large or small, works for some collective benefit that by its very nature will benefit all of the members of that group in question. Though all of the members of a group therefore have a common interest in obtaining this collective benefit, they have no common interest in paying the cost of providing that collective good. Each would prefer that the others pay the entire cost, and ordinarily would get any benefit provided whether he had borne part of the cost or not.”* (Olson, 1965, p. 21)

The collective action problem, also referred to as the free-rider problem, will be defined as a scenario in which it would be best for all members of a group to cooperate and act collectively, but individual interests incentivise group members to withhold contributions towards the collective good and free-ride instead (Hindmoor, 2006). Given the severe consequences of climate change, it is crucial to cooperate and achieve the collective good of environmental protection and climate action. Conversely, the collective action problem, more explicitly free-riding, can result in no or less than the optimal provision of the collective benefit (Ostrom, 1990). Hence, free-riding can jeopardise climate change mitigation and potentially exacerbate environmental degradation and global warming.

This thesis will address the collective action problem in the context of international governance. Specifically, I seek to answer the two following research questions: *What specific collective action problems do countries face regarding climate governance? What feasible solutions can be* *implemented to mitigate free-riding and foster collective action effectively*? To address these questions, I will employ game theory as a framework to examine countries' climate policies, identify potential collective action problems and explore measures to effectively address the lack of cooperation and collection action.

Overall, the objective of this thesis is to show that different countries encounter *specific* collective action problems in climate governance, which require *distinct* solutions. Thereby, this thesis represents a novel addition to the extensive discourse on collective action and climate change mitigation: It *integrates* a game-theoretical evaluation of the collective action problem with a comprehensive analysis of how significant countries adopt different approaches towards climate change mitigation. This *combination* helps explore bespoke solutions promoting climate action in different countries. Thus, it may offer potential for future research focused on tackling various collective action problems in the context of international efforts to mitigate climate change.

First, the thesis will review the relevant literature from the field. Chapter 2 will introduce game theory as a conceptual tool, along with its underlying assumptions, in the methodology section. The main part will explore the collective action problems in the climate governance of four global players, namely, China (Chapter 3), the USA (Chapter 4), India (Chapter 5) and the EU (Chapter 6), and evaluate potential solutions to address the issue of insufficient climate cooperation. Finally, Chapter 7 will provide a summary, a comprehensive discussion of the research findings and present concluding remarks.

1.2 Literature review

The literature review can be divided into two sections: the first explores research on game-theoretical models that illustrate the collective action problem, and the second concentrates on the measures to counteract free-riding and enhance cooperation in climate action.

DeCanio and Fremstad (2013) explore in their analysis of climate diplomacy several climate games with an emphasis on the transition from the Prisoner's Dilemma to a Coordination game, which is helpful for understanding the free-rider problem in both two-player and *n* player scenarios. Building on this work, Kennedy and Basu (2014) assess the same games focusing on technological spillovers, using China and the USA as examples to extend the literature on climate negotiations. Another typology of countries' strategies in the context of climate action is provided by Finus (2001) and Heugues et al. (2013), who developed and refined a global emissions game to consider exogenous parameters, namely other countries' emissions. Both games above view a country as a single entity influenced by other countries' climate policies. In contrast, Putnam (1988) employs a two-level game approach to international negotiations, separating the diplomatic mediation into an international and a domestic level, where both levels significantly impact the other. Regarding the collective action problem, Olson and Zeckhauser (1966) saliently contributed to the analysis of this problem by constructing a game-theoretic model to demonstrate how different evaluations of NATO members result in the underprovision of the collective good. These last two approaches serve as a methodological foundation that can be transferred into the context of climate governance. Wood (2011) gives an overview of the climate games in the field and further summarises approaches to mitigate free-riding and foster international cooperation for greater climate action.

Wide-ranging literature exists aimed at remedying free-riding incentives in the Prisoner's Dilemma. Snidal (1991) examines how Prisoner's Dilemmas can be transformed into cooperative games by increasing the number of players or reducing the importance of relative gains compared to absolute gains for the players. The understanding of the relationship between relative and absolute gains was further extended by Powell (1991), who evaluated determining factors of the gains with emphasis on changes in the countries' behaviour and Rousseau (2002), who examined the nature of the opponent and the contextual situation for relative versus absolute gains. Another subfield of research addressed the Prisoner's Dilemma by exploring the consequences of the infinite repetition of the game. Axelrod and Hamilton (1981) famously demonstrated that when players use a reciprocity-based strategy and cooperate in the first round of the repeated Prisoner's Dilemma, cooperation can emerge and persist, as illustrated by a computer tournament he organised and evaluated. In addition to the Prisoner's Dilemma, other games, such as the global emissions game, can depict the collective action problem. Gerber and Wichardt (2009) proposed the implementation of a deposit mechanism that induces countries to commit to emissions reduction. Another solution by Nordhaus (2015; 2020) suggests the formation of climate clubs that penalise polluting countries outside the club as an incentive to increase collective climate action through mutual abatement. On the other hand, a way to promote cooperation for the collective good within agreements involves a marginal cost-sharing scheme, as proposed by Putnam (1988). In the literature, further subfields concentrate on promoting (collective) climate action domestically, such as by raising climate awareness through education with a focus on intergenerational justice (Sanson

& Burke, 2020) or by tackling misinformation in the climate context (Van Der Linden et al., 2017). Internationally, cooperation for collective action can be fostered through measures involving increased bargaining power (Kroll & Shogren, 2008; Clare, 2014) and the influence of multilateral powers (Milewicz & Snidal, 2016).

Overall, game theory and international relations literature can provide valuable insights for understanding and mitigating the collective action problem. Many recent studies have situated the issue of free-riding and lack of cooperation in the context of climate action. However, few researchers have considered specific countries and their climate governance when analysing the free-rider problem. This thesis aims to address this gap in the literature by combining an analysis of countries' climate policies with extensive research on the collective action problem.

2 Methodology

2.1 Using game theory as a conceptual tool

There are several reasons why game theory is a valuable tool for analysing international climate governance. Above all, game theory can turn the complex settings of international and domestic environmental politics into simple models. This simplification, which involves the exclusion of less significant factors, helps to understand, and evaluate the crucial incentives of stakeholders and predict outcomes for potential climate cooperation:

> *„Game theory models do not take into account various factors, such as social and cultural factors, which frequently affect international cooperation* (…) *The aim of game theoretical analysis is not to cover all factors involved in international cooperation but rather to focus on certain factors and explore the interplay between them. Such an analysis may seem simplistic but the very simplification can clarify complex interactions" (Hirsch, 2009, p. 510).*

Another advantage of using game theory concerns the absence of a central authority which could internationally enforce environmental policies (Chander, 2018). The reason for this is the principles of sovereignty, equality, and non-intervention for nations of the 1648 Treaty of Westphalia that make it difficult to establish a central authority (e.g., Nordhaus, 2015). The absence of supranational enforceability highlights the importance of the incentives underpinning the decision-making processes of nations concerning climate policies. Game-theoretic models offer the possibility of depicting these incentives of the countries and the resulting implications for potential cooperation.

Lastly, the simplicity of the models facilitates the evaluation of changes in the incentives and determining factors affecting the countries' climate choices. Consequentially, adjustments that promote climate cooperation and mitigate the collective action problem can be examined.

To summarise, game theory as a conceptual tool facilitates the understanding of international climate governance by focusing on the pivotal incentives of stakeholders. What is more, it has the potential to assess collective action problems and enhance international cooperation in addressing climate change. The discussion section will illustrate the disadvantages of utilising game theory in the context of climate governance.

2.2. Assumptions for the games and models

Games (in their normal form) require three components: players, strategies for the players to choose and outcomes as payoffs that result from the (played) combinations of strategies. Several large countries will be among the players of the subsequent games. They are considered unitary players wherein one entity, such as a government, a general secretary, or a Senate, represents the interest of various stakeholders such as individual citizens, companies, NGOs or (environmental) committees. Therefore, in the following games, the unitary player will make decisions and act on behalf of the aforementioned groups.

Furthermore, it is presupposed that the players are rational and seek to maximise their expected utility, typically represented by the payoff attributed to the possible outcomes of the game (e.g., Owen, 2013). The utility a player derives from playing a particular strategy can be influenced by various factors such as costs associated with emissions abatement, the financial benefits of reduced exposure to environmental hazards and, importantly, the other players' strategies.

Moreover, it is assumed that all players accept the rationality of the others and know the rules of the games, including the requirement to select one of the available strategies and the possible payoffs of every player (e.g., Hindmoor, 2006). Therefore, the games presuppose perfect information: in a two-player game, player *i* will know her possible payoffs and the expected payoffs for player *j* and will know that player *j* anticipates all payoffs and that he has knowledge that she knows this, and so forth.

Another significant concept that will be employed is the Nash equilibrium or equilibria of games. These are sets of strategies that represent the mutual best responses for the players. In other words, players have no incentives to deviate from a strategy since, given the other player's decision, they cannot increase their payoff when switching to another strategy (e.g., Stengel, 2022). These equilibria, i.e., solutions of the games, are of particular interest for the analysis as they depict a stable situation that allows the interpretation of the implications of the players' decisions.

Finally, noncooperative games will be used to portray the player's possible strategies in climate governance. This implies that players act independently and cannot be compelled to implement environmental measures. Therefore, promises or commitments made between players are not binding, and cooperation, e.g., through climate treaties, is only feasible when it aligns with the self-interest of the players (e.g., Mesquita, 2009). In contrast, cooperative games assume that agreements between the players are binding. One may object to the non-cooperative nature of the games by referring to the Paris Climate Agreement or other international climate treaties; however, these agreements are voluntary, and countries may fail to honour their commitments and promises. As Nobel laureate William Nordhaus points out, "in 2020 (…) there is no binding international agreement on climate change" (Nordhaus, 2020, p.10).

From the international relations perspective, the games are situated in a realistic context where self-interest plays a crucial role and is shaped by positive (e.g., financial gains) and negative (e.g., penalties) incentives. However, the actual outcomes of climate governance can be more cooperative than predicted by the games, for instance, when actors behave irrationally and do not maximise their expected utility, which is why the game's outcomes work as "lower benchmarks" of possible cooperation (Wood, 2011, p.154). Consequently, the games represent only the minimum cooperation between countries; more cooperation than expected from a realistic viewpoint is both feasible and advantageous. Limitations to the assumption will be discussed in Chapter 7.2.

2.3 Choosing the countries as players for the game-theoretic models

This thesis paper explores the environmental strategies employed by major CO_2 polluters, namely China, the United States of America (USA), India, and the European Union (EU). CO_2 is a primary greenhouse gas responsible for climate change and global warming. In 2021, China accounted for 30,9% of global CO_2, followed by the USA with 13,5%, the EU with 7,5% and India with 7,3%

of CO_2 emissions (Tiseo, 2023). Notably, these percentages refer to the current total, not per capita emissions, and do not consider historical greenhouse gas emissions.

Consequentially, the environmental policies of these four major global players (the EU comprising the current 27 member countries) have a decisive impact on determining the effectiveness of climate change mitigation efforts for the planet's future. What is more, these countries can establish climate treaties or other cooperative agreements during the course of negotiations. The annual Conference of the Parties (COP) held as part of the United Nations Climate Change Conference (UNFCCC), as well as domestic parliamentary debates of the individual countries and meetings of the EU institutions such as the EU Commission, offer possible scenarios for the negotiations over international climate governance. The discussed games can help predict climate negotiation outcomes, which will be specified next.

2.4 Methodological approach for the analysis

For every player, I will employ the same approach for the analysis.

First, the crucial circumstances that pertain to a country's climate governance are identified, primarily encompassing economic and political factors that determine the player's climate policies. For this, I will break down a country's climate governance into a few salient factors to ensure clarity and simplicity.

Secondly, I construct game-theoretic models that reflect and depict these crucial factors. Here, the respective player faces other individual players or all global (n) countries simultaneously.

The third step involves analysing the bespoke game-theoretic models concerning the collective action problem. The aim will be to pin down the factor(s) responsible for the free-rider problem and, thus, the lack of climate cooperation and investigate how the found collective action problems differ.

Lastly, with ideas and concepts from the literature, I will explore how the found collective action problems can be remedied or mitigated to foster more cooperation in climate governance. This may involve altering and modifying the games that represent countries' environmental strategies to find effective measures that could be implemented for more climate cooperation. The focus is on finding concepts that efficiently address the particular collective action problem. Moreover, the last step evaluates the feasibility of the potential ideas to enhance climate cooperation in practice.

The discussion section further elaborates on the possible comparisons and categorisation of the game-theoretic models and more comprehensive solutions to greater cooperation in international climate governance.

3 China and the prisoner's dilemma?

3.1 Two scenarios for the case of China

The analysis of China's climate governance is divided into two scenarios. The first characterises China within a bipolar structure alongside the USA, while the second posits China in a multipolar setting with *n* countries. This is due to the uncertainty regarding which scenario accurately captures China's perceived position (bipolar vs multipolar) within the global structure. To scrutinise the two scenarios, it is necessary to derive the political and economic factors that shape China's climate governance.

China seeks to become the largest economy, thereby surpassing the economy of the USA, which according to its current trajectory, might already be the case in a decade (Zhu & Orlik, 2022). This creates incentives for Chinese policymakers to abstain from any interventions in the short term that might jeopardise the goal of overtaking the USA economically or endanger China's status as (a) global superpower. However, adhering to the Paris Agreement's goal of limiting global warming to 1.5° C could incur significant abatement costs ranging from 2.8 - 5.7% of the GDP by 2050, as Duan et al. estimated (2021). In contrast, the costs of climate change to China are expected to lead to GDP losses of "only" 0.5 – 2.3% beginning in 2030 (World Bank Group, 2022). The World Bank Group predicts that the costs for achieving net zero[1] in the power and transport sector alone could amount to 13-17 trillion for China by 2060 (2022). These costs are equivalent to China's total GDP of 2021, representing 18.4% of the global economy (He, 2022). Given the high abatement costs compared to potential climate change losses, China may be hesitant to implement environmental policies that could jeopardise its economic goals, although measures such as replacing finite energy sources are necessary for long-term economic growth. Assuming similar ratios of abatement costs and climate change losses for other countries, China could achieve a comparative

[1] The idea of net zero or climate neutrality aims to establish an equal balance between the amount of produced and removed or offset greenhouse gases in a city, country etc. and is widely considered as crucial for limiting global temperature rise.

advantage if the opposing player(s) abate emissions whilst China continues to pollute.[2] This advantage may be amplified by the dynamic of emissions abatement costs, which imposes high financial costs on early adopters compared to those who wait and profit from the abatement technologies that were developed in the interim (Kennedy & Basu, 2014). Overall, economic and geopolitical are hence the crucial factors in China's climate governance.

3.2 China in a bipolar setting alongside the USA

The first scenario situates China in a bipolar setting alongside the USA. The reason for choosing the USA as its counterpart and thus the primary determinant of China's game is the increasing economic and political rivalry between the two global powers. This rivalry is characterised by one power seeking to dominate the other economically, creating a collapse or survival scenario in the bipolar structure (Zhao, 2021). Especially political struggles, e.g., concerning Taiwan or the chip markets, foster a hostile environment in what has been described as a "new cold war" (Osnos, 2023). Thus, China's approach to climate change (and other international issues) will likely depend on the decisions taken by the USA.

Concerning the possible choices in climate governance, there are two available options, "Abate" or "Pollute", which both countries face in a one-time decision. Although limiting the choice to only two options sacrifices the potential variety of intermediary options, it can provide more clarity in analysing the scenario. Additionally, both countries are accountable for a combined 44% of global CO_2 emissions (see 2.3). As a result, the direction these two countries choose in the near future, whether to "Abate" or "Pollute", will significantly influence global efforts against climate change. This decisive and imminent impact justifies omitting differentiated choices and sequential time frames.

Furthermore, given the aforementioned bipolarity, one can argue that both countries, although being asymmetric players, prefer the discussed comparative advantage of continuing to pollute whilst the other abates emissions over mutual abatement. Similarly, the choice of both to "Pollute" is preferred over unilaterally abating when the other country pollutes. Lastly, the outcomes of the two former choice profiles are preferred over the latter two due to the comparative (dis)advantages.

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[2] Although China seeks to peak CO_2 emissions by 2030 and accomplish carbon neutrality in 2060, the carbon emissions are rising again after a decline during the coronavirus lockdowns, e.g., the recent expansion of coal power plants has increased and reverted to levels of 2015 (Shepherd, 2023). Therefore, the current strategy of China cannot be considered a (sufficient) emissions abatement strategy.

These assumptions and preferences in the form of strategies and payoffs can now be depicted as a game.

3.3 China and the classical Prisoner's Dilemma

With the players and two choices, namely strategies, a 2 x 2 order game emerges where the players simultaneously face the one-time decision to "Abate" or "Pollute" (*Table 1*).

The classical Prisoner's Dilemma of China

		USA: Abate	USA: Pollute
China	Abate	r , l	s , n
	Pollute	t , m	p , k

(t > r > p > s; n > l > k > m)

Table 1, China's prisoner's dilemma – adapted from (Kennedy & Basu, 2014, p.186)

The payoffs for the two countries are denoted by the letters t, r, p, s, n, l, k and m, which give the possible outcomes an ordinal structure and indicate the players' preference for specific outcomes over the other.[3] If, for example, t > r, then the strategy that yields the outcome t is preferred over the strategy that may result in r. The payoffs reflect the ordinal preferences t > r > p > s and n > l > k > m for China and the USA, respectively. They are aligned with the player's discussed preferences of some outcome over the other concerning the combination of played climate strategies ("Pollute" or "Abate"). In *Table 1*, these payoffs transform the first game into a classical Prisoner's Dilemma (PD).

China's best outcome in this game would be if the USA decides to abate while China continues to pollute, as demonstrated by t > r. In addition to t > r, p > s holds, which is why China always prefers to pollute regardless of the USA's strategy. Hence, "Pollute" is China's dominant strategy in this game, i.e., the payoff is always higher than when playing the "Abate" strategy. The payoffs

[3] The left player (China) receives the left letter and the player above the table (USA) the right letter as payoff.

for the USA entail the same dominant strategy, which is why the Nash equilibrium and solution of the game is “Pollute”, “Pollute” (see 2.2).

However, this solution leads to a tragic implication where both countries would receive better outcomes if they would cooperate to play “Abate”, and “Abate” as $r > p$. Thus, they find themselves in a dilemma where the rational individual choice generates a lower payoff than possible (DeVos & Kent, 2016). Such an outcome is also considered Pareto or socially inefficient since both players’ payoffs could be increased by cooperating to “Abate” without reducing one player’s payoff. In this game and thus the bipolar scenario, this socially inefficient outcome manifests in the environmental harm caused by both players’ rational decision to choose “Pollute”.

3.4 China in a multipolar setting with *n* players

The second scenario analyses China’s climate strategies in a multipolar setting with *n* players. In this, unilateral pollution, with its comparative advantage, no longer outweighs mutual abatement for China. This is because, without the intense competition in the bipolar scenario, the focus shifts from relative gains for economic and geopolitical power to the absolute gains of climate cooperation. More specifically, these gains of climate cooperation, such as fewer climate hazards or technological advancements, are more important for China in a multipolar structure than in the bipolar rivalry where its comparative advantage towards the US matters most for China.[4] Thus, China’s preferences change. Mutual abatement of all players is preferred over unilateral emissions abatement when China pollutes. However, it is still assumed that China prefers collective polluting over a case where all *n* countries pollute, and China abates due to the fear of economic disadvantages. The outcomes of the two former strategy profiles are preferred over the latter.

The players are again considered to be asymmetric due to significant differences in size, population wealth, etc. Nevertheless, all players are assumed to have the same preference (not absolute payoffs) as China over the outcomes of climate strategy profiles suggesting that despite the geopolitical competition, they now grasp the magnitude of the climate crisis (DeCanio & Fremstad, 2013). Thus, the countries are willing to prioritise the planet’s survival over self-interest for survival and prefer mutual abatement over polluting while others abate. For reasons of simplicity, it is further assumed that the countries can choose between the two options of pollution or emissions

[4] These gains and positive externalities of climate cooperation and mutual abatement are further discussed in section 3.6. In addition, the relationship between relative and absolute gains will be clarified in section 3.8.

abatement simultaneously during the course of negotiations. However, the idea of a one-time decision is replaced by the concept of multiple negotiation rounds, for instance, the annually held COPs, in which the countries can decide on the two strategies. In the next step, a game for these new assumptions is constructed.

3.5 China and the stag hunt

The second game diverges from the first due to the alterations in crucial assumptions. First, the number of players is expanded to *n* players, rendering China no longer directly opposed to the USA but rather to every other country and their climate strategy. From the perspective of China, a 2 x 2 matrix can be established with China and *n*-1 as the second player that combines the payoffs of every player except China. Here, the *p* denotes the percentage of the *n*-1 players that abate, with 1-*p* representing the share of polluting players. Thus, the cumulative payoffs of *n*-1 have to be multiplied by the respective *p.* Furthermore, the assumed preferences over the outcomes of the climate strategies are represented through the playoffs (r > t > p > s; x > z > w > y). In the initial negotiation round, the share of *n*-1 countries that abate or pollute is unknown, which is why nature "chooses" i.e., *p* = ½. With these game-theoretic new parameters specifically payoffs for the countries, the game shifts from a PD to a stag hunt (*Table 2*).[5]

A stag hunt game with *n* players

		n-1: Abate	*n*-1: Pollute
		p	1- *p*
China	Abate	r , x	s , z
China	Pollute	t , y	p , w

(r > t > p > s; x > z > w > y)

Table 2, China's stag hunt – adapted from (DeCanio & Fremstad, 2013, p.181)

[5] This game is also known as assurance game, trust dilemma or coordination game. The name stag hunt alludes to a problem coined by Jean-Jacques Rousseau in which two hunters must decide whether to separately hunt a hare (less meat) or cooperate in hunting a stag (more meat) together.

In the present scenario, the new preferences of the Stag Hunt game (r > t; x > z) enable the possibility of cooperation between countries and mutual abatement, as *two* Nash equilibria now exist: "Abate, Abate" and "Pollute, Pollute". This occurs because equally polluting, given that the other player pollutes, maximises the payoff (p > s; w > y) as in the PD. However, when the other player opts to abate, mutual CO_2 reduction now leads to the highest outcome (r > t; x > z). Therefore, both strategies become rational as mutual best responses implying that all players decide to abate or all players pollute. In reality, the large number of countries makes a unitary decision unlikely. What is more, the share of abating countries (*p*) can change in the course of the subsequent negotiation rounds. The implications of different *p*-levels in the stag hunt will be analysed next.

3.6 Including different shares of abating countries (*p*)

To address this issue, examining the externalities of pollution and abatement is necessary. If other countries decide to pollute, this produces negative externalities for China due to extended global warming. The negative repercussions include the effects of climate change, such as coastal flooding, erosion, and storm surges (World Bank Group, 2022). In contrast, positive externalities can arise if other countries adopt abatement measures. China can, for instance, benefit from technological spillovers from the abatement measures of other countries. Using simulations with 60 countries, Huang and Lv demonstrate that in the electricity sector, technological spillovers could substantially reduce China's CO_2 emissions from trade (2021). Such technological progress could, for example, be the near infinite clean and wasteless energy from nuclear fusion, considered a significant breakthrough for a potentially broad energy source (e.g., Stallard, 2022). As a result, the cost of abatement and the benefits of China's strategies are contingent on the extent to which other countries reduce their emissions (*p*) and share their abatement technologies. The greater the number of countries engaging in abatement, the more likely China will profit from technological spillovers, resulting in less expensive mitigation measures, and vice versa. The varying levels of *p* in the stag hunt can also be depicted in a game-theoretic model, *Fig. 1*:

A stag hunt game with different shares of abating countries

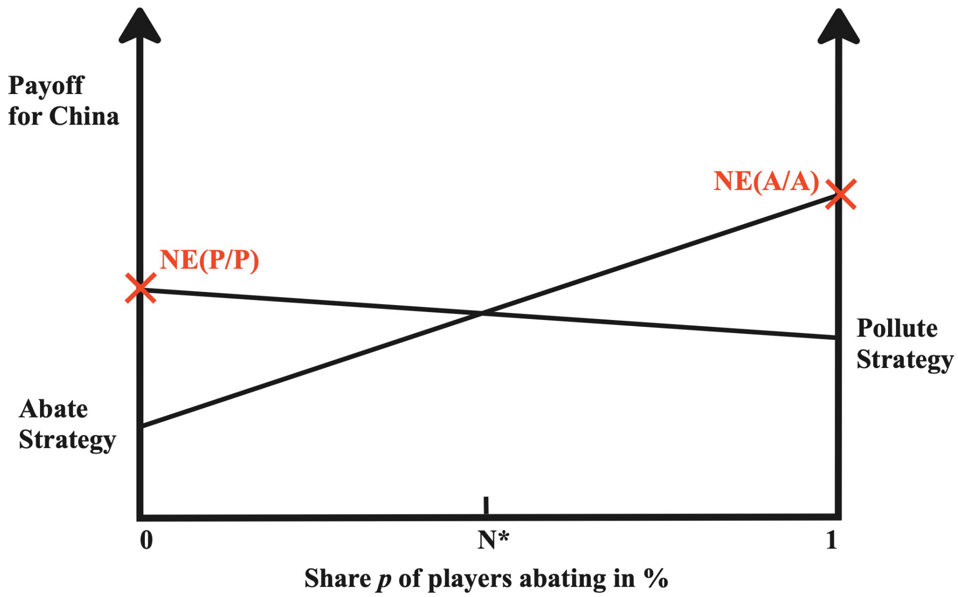

Fig. 1, Modified stag hunt – adapted from (DeCanio & Fremstad, 2013, p.184)

The two strategies are now shown as lines indicating China's payoff for every value of *p*. The two Nash equilibria NE(P/P) and NE(A/A) are visible where "Abate", "Abate" is the Pareto-efficient solution as in the PD.[6] The point in the model where the two lines intersect signifies the turning point N* where the rational strategy for China shifts from "Pollute" to "Abate". Above (right of) N*, the positive externalities, such as technological spillovers, result in the Nash equilibrium (NE(A/A)) as "Abate" yields higher expected payoffs than "Pollute". Below (left of) *N*,* negative externalities of pollution induce all countries to ultimately revert to the Nash equilibrium (NE(P/P)) where the payoffs of "Pollute" are superior to those of "Abate".

Several implications can be drawn from this. First, abating is one of the two rational strategies for China and every country in the second game (*Table 2, 3*) with *n* players, distinguishing the stag hunt from the dualistic PD. Secondly, China's decision to choose "Abate" (or "Pollute") depends on *p*. Therefore, China will rationally choose to follow the "Abate" strategy only when it believes that a sufficient number of countries decides to abate as well in the course of (subsequent)

[6] For the PD, the "Pollute" strategy would be a parallel line *above* the "Abate" strategy line as "Pollute" always leads to higher outcomes independent of what the other players choose (see *Table 2*).

negotiations. The reasons for other countries to abate (before N*) may include economic, political, or social factors, such as high vulnerability to climate change, that exceed the scope of these simple games. Thirdly, China is thus incentivised to delay CO_2 emissions reduction until enough countries abate and N* is exceeded. Only then, if it is believed that enough countries will reduce emissions and technological spillovers increase, will China's payoff for abating be higher than the payoffs of polluting.

3.7 Implications and consequences

Overall, the two potential scenarios for China's climate governance can be expressed through two games. The underlying reasons for choosing a strategy are reflected in the preferences over different outcomes (payoffs). These payoffs are determined by the aversion of China to economic decline, particularly in the context of intense competition with the USA. The classical Prisoner's Dilemma represents the bipolar geopolitical perspective between China and the USA. In contrast, the Stag Hunt illustrates a multipolar view where cooperation between countries, namely mutual abatement, is hypothetically achievable when enough countries abate and facilitate technological spillovers. In the former game, the rational strategy for China is to pollute, while in the latter game, to wait until it believes that enough countries will reduce their emissions before switching from pollution to abatement. Importantly, the game's payoff for all players abating together is *always* higher (Pareto-efficient) than the payoffs for the pollution strategy profile. Therefore, the Nash equilibria of both games indicate that China should pursue primarily a socially inefficient strategy (although in the second game, it is possible that China rationally chooses the socially efficient strategy if enough countries abate). With this outcome, the games indicate that China faces a collective action problem, as defined and discussed in Chapter 1, due to the discussed counterproductive economic and political incentives. Thus, overcoming these incentives is necessary for China to enable an efficient fight against climate change.

3.8 Cooperation in the PD: reducing relative gains

The following section examines how solutions from the literature, which promote (greater) climate cooperation, can be applied to the games that represent the different scenarios of China's climate governance. It is important to note that such solutions must not be confused with the Nash equilibrium/equilibria, which are the solutions of the games. Instead, the *solutions* for greater cooperation and the collective action problem, e.g., with PD of China, might involve modifications in the games' parameters that entail new equilibrium solutions with increased cooperation. This can be accomplished, for example, by adjusting the payoffs for the possible outcomes of the strategies so that the best response to the other player becomes to cooperate and mutually abate rather than to continue polluting. In this way, cooperation becomes the rational strategy for the players in the altered games.

The first two *solutions* for more collective action in climate governance address the first of China's possible games, i.e., the PD with China and the USA as players. The PD assumes that the unilateral pollution payoff is higher than the mutual abatement payoff (t > r). This is different in the *n* player stag hunt, where the payoffs of t and r are changed (r > t, x > z), and cooperation (mutual abatement) is possible. One approach to increase collaboration is to change the payoffs of the game so that it resembles a stag hunt or a different game with "Abate" and "Abate" as (one) Nash equilibrium. Consequently, the two countries' preferences over outcomes of climate strategies would have to change and thus, the importance of absolute and relative gains. In the discussed PD, the relative gains trump absolute gains for the players due to the intense competition in the bipolar structure, making cooperation impossible. However, Snidal seminal work suggests that the chances of cooperation can increase rapidly if relative gains matter no longer exclusively or the game is extended to three or more players (1991). Since bipolar structure cannot exceed two players, the possibility of cooperation in the game thus depends on the importance of relative gains for China (and the USA)

The significance of relative gains is influenced by factors such as the perceived nature of the opposing country. When an opponent is grasped as an economic or military threat, this increases the focus on relative gains (Rousseau, 2002). Therefore, the importance of relative gains for China could diminish if the USA's economic or military power were to decrease or be perceived by China as reducing. However, both scenarios are unlikely due to the ongoing competition for global superpower status.

Moreover, the benefits of the unilaterally polluting country determine the preferences and payoffs in the PD. Only if the relative gains can be used and exploited are the payoffs associated with "Pollute" maximised. This requires a set of beneficial opportunities for the polluting country and constraints for the abating country (Powell, 1991). Therefore, to reduce the relative gains, the disadvantage of the solely abating country and the advantages of the unilaterally polluting country should be decreased.

Presently, the high costs of abatement, which may harm economic growth, act as a disadvantage for the abating country, while continuing to pollute avoids such costs. Lowering abatement costs could hence reduce these (dis)advantages. However, although emissions reduction costs may decline in the future due to scientific advancements and new technologies, this *solution* is not applicable in the present: if the abatement cost were *already* lower than the benefits from polluting, the PD would not arise in the first place.

Additionally, the advantage of exploiting relative gains could be reduced by (economically) penalising the polluting country, specifically China, through measures such as trade tariffs. This would diminish China's economic growth and thus reduce the advantages of unilaterally polluting. However, due to the complexity of supply chains and dependencies on Chinese consumers, effectively and consistently penalising China as a *solution* may be unrealistic.[7] Perhaps a central authority could be established to penalise polluting countries effectively. A *solution* with a central authority for penalising will be discussed in Chapter 5.6.

3.9 Cooperation in the PD: repeated games

In the attempt to *solve* the collective action problem illustrated in China's PD, the concept of repeated games will be examined next. Repeated games are applicable when the same players encounter the same game with unchanged possible strategies and payoffs in the future. In the context of climate negotiations, for example, the annual meetings of the UNFCCC support the idea of repeated PDs, as China and the USA face each other regularly while playing the same game (replacing the previous assumption of a one-time decision).[8] This idea of a repeated PD will be the basis for the following *solution*.

The time horizon is crucial for repeated PDs. If the game is considered *finite*, the Nash equilibria remain unchanged compared to the one-shot PD (except when a player knows that the other always cooperates or uses a reciprocity-based strategy). This is because in the last period of the finite game, "Pollute" is the rational strategy for both players (as it is a one-shot PD). This fact is common knowledge in the penultimate round, so it cannot affect the last round. Consequently, it is

[7] Currently, there exist already many tariffs of the USA on China. As China is present in many global markets e.g., the EU or the APAC regions, many countries would have to participate in penalising the continued pollution of China. This makes effective penalisation even more unrealistic.
[8] The fact that no binding climate treaty by the UNFCC and especially between China and the USA has resulted from more than twenty conferences indicates that the game's parameters have not changed in such a way that cooperation and collective abatement have become the rational strategy to play. Thus, the same repeated game is assumed.

again rational for both players to pollute; thus, the game unravels until the players pollute in every round (Mccarty & Meirowitz, 2007). However, the situation differs with an *infinite* time horizon.

Robert Axelrod and William D. Hamilton famously demonstrated through a computer tournament that the highest payoffs in an infinitely repeated PD can be achieved using a simple reciprocity strategy that starts with cooperating, i.e., abating (1981). This outcome indicates that cooperation is feasible in a repeated PD since it generates higher payoffs compared to always defecting, i.e., polluting. The key reason for this potential cooperation lies in the reciprocity inherent in the simple reciprocity strategy, also known as Tit for Tat. This strategy starts with abatement and continues with the same strategy the other player used in the previous move. If one country decides to pollute in a round and exploit the other, the retaliatory response of the aggrieved country follows in the subsequent round, thereby reducing the payoffs of the defecting countries (Axelrod, 1981).[9] Thus, the players are incentivised to refrain from polluting to maximise their payoffs. Importantly, without a determinate last round, there is no more incentive to pollute in the last round, which prevents the game from unravelling into a series of one-shot PDs.

Moreover, for the simple reciprocity strategy, "the foundation of cooperation is not really trust, but the durability of the relationship" (Axelrod, 1984, p. 5). Hence, to achieve cooperation, a long-time horizon and stability in the relationship can compensate for possible mistrust or antagonism between the players. In the case of China and the USA, this condition of durability may be satisfied but is threatened by the changes of the unitary actor, for instance, by newly elected governments. In addition, the simple reciprocity strategy presupposes an initial cooperation attempt from at least one player. Consequentially, the significance of the bipolarity for the two players, China and the USA, will again determine whether one country will endeavour to abate initially. With this, the *solution* of the infinitely repeated PDs hinges on two key factors: the infinite time horizon and the players' perception of their complex relationship, which may or may not justify initial abatement.

Overall, some *solution* attempts for the Chinese PD as a one-shot game and with an infinite time horizon were explored. In the one-shot PD, proposals to diminish the relative gains for polluting appear unrealistic in the current bipolar situation. For the infinitely repeated PD, cooperation is possible if there is (a unilateral) effort of the players to transcend a bipolar competition and to

[9] This requires that the retaliation in the next game is not discounted to highly by the defecting player (Axelrod, 1984).

initiate abatement with a strategy of simple reciprocity in mind. In the current "new cold war" between China and the USA, the probability of such initial efforts is, however, considerably low.

3.10 More cooperation in the *n* player game

In the *n* player stag hunt, the potential for cooperation exists. However, China has incentives to wait until it believes that enough countries abate before also switching from pollution to emissions reduction. This delay is socially inefficient as higher overall payoffs are possible with mutual abatement than collective polluting. Thus, "solving" this collective action problem necessitates providing incentives for China to switch to an "Abate" strategy before the turning point N* is reached (*Fig. 1*).

One approach to induce China into abating sooner is through reputation. With a series of laboratory experiments, Willer finds that when players obtain status rewards for contributions to the collective goal, such as emissions abatement, it can enhance subsequent contributions of players and the overall group motivation (2009). Thus, status rewards could incentivise China to abate earlier, thereby mitigating the collective action problem.

Moreover, the reputation of China has recently declined, with unfavourable global views of China reaching a historical 80 %, e.g., due to issues such as strict Covid-19 management or human rights violations against the Uyghurs (Silver et al., 2022). This decline in reputation has also led to economic consequences, such as the suspension of EU investments and increased concerns regarding corruption and debt in the Belt and Road Initiative (BRI) (Kurlantzick, 2022). Therefore, it is reasonable to assume that China seeks to halt this reverse of its negative reputation.

Considering this, a potential approach to address the Chinese collective action problem involves offering status rewards from the other *n*-1 players for China's initial abatement efforts (as well as those of other countries). Such rewards might include measures like reversing diplomatic boycotts or establishing new investment agreements. Thus, enhancing China's reputation through status rewards could motivate to engage in more abatement efforts. Like the other potential *solutions* discussed, status rewards do not require a central authority but instead rely on the individual players' willingness to reward contributions to collective action (Willer, 2009). As such, the *solution* of this approach hinges on the players' initiative: China must take action to abate earlier than predicted by the model (if p > N*). At the same time, other countries must reward this effort by enhancing China's reputation and incentivising further emissions reductions. Especially the increasing climate ambition of prominent players such as the EU and their possible status rewards to other abatement efforts render this *solution* increasingly conceivable.

4 An extensive game: The USA and domestic ratification

4.1 The USA and the polarisation in climate issues

This chapter scrutinises the climate governance of the USA and its implications. Despite being characterised as an opposing player in China's first game, the focus of the analysis shifts away from China to take a closer look at the critical determinants of the USA's climate policy. The polarisation and disagreement on climate action between Democrats and Republicans are assumed to be the pivotal factors in shaping the country's stance on climate change.

The Democratic Biden administration has set forth an ambitious target of halving greenhouse gas emissions by 2030, with a long-term goal of achieving net zero emissions by 2050 (Greve, 2022). Thus, measures to reduce emissions have been implemented, such as the Inflation Reduction Act, with $369 billion of funds designated for climate investments. It is estimated that these measures could potentially reduce up to 40 % of greenhouse gases by 2030 (Jenkins et al., 2022). However, the climate bill only received the support of Democratic senators, and no Republican senator voted in favour of it (Friedman & Weisman, 2022). In fact, a mere 16% of Republicans and Republican leaners generally acknowledge climate change as a significant problem compared to 63% of Democrats (Doherty & Gómez, 2022). As a result, the support of Republicans for emissions abatement efforts in the USA is significantly lower than that of Democrats.

To demonstrate the domestic and international implications of this polarisation in climate governance in the USA, the next game illustrates these key factors through a hypothetical climate treaty, e.g., for collective emissions reduction that the USA can join. For this, the concept of the international and domestic level must be clarified first.

4.2 Introducing the international and domestic level

The forthcoming game will draw on the theoretical underpinnings of the two-level game approach initially proposed by Robert Putnam. In this approach, decision-makers are confronted with two interrelated political levels during international negotiations: the international level (first level) and the domestic level (second level). At the first level, decisions are made and implemented, while at the second level, decisions made at the first level must be accepted by the domestic actors, such as through ratification by the parliament or national assembly. Since the perspectives on a country's national interest can diverge between the two levels, policymakers are advised to "reconcile domestic and international imperatives simultaneously" (Putnam, 1988, p.460). Based on this conceptualisation of the two-level approach, a game of climate negotiations for the USA can be constructed.

At the international level, the president can opt for a binding climate treaty with one country, for instance, China or several countries (even a global climate treaty could be considered). At the domestic level, these proposed treaties must subsequently be ratified by two-thirds of the Senate, which consists of 100 members.[10] Thus, the negotiators at the international level must ensure that the climate treaties align with the national interests at the domestic level in order to secure ratification by the Senate of the United States of America (Wood, 2011).

4.3 Explaining the players' preferences

At the international level, the president prefers to join an ambitious instead of an unambitious climate treaty to highlight and promote his efforts to reduce emissions.

For a climate treaty to be ratified at the domestic level, 67 (two-thirds vote) of the 100 senators would have to consent. This entails that both Democratic and Republican senators would have to vote for the proposed treaty.[11] Given the strong resistance of Republican senators to climate change measures, however, an ambitious treaty is unlikely to secure the necessary support in the Senate. Vice versa, a more unambitious treaty with fewer and milder regulations for the economy and lower emissions reductions has a higher chance of achieving the two-thirds majority. In the latter case, some Republican senators that already support climate measures could ratify the (less ambitious) treaty along with all the Democratic senators (Friedman & Weisman, 2022). Hence one can assume that the Senate as a whole (the average senator) prefers to ratify an unambitious treaty rather than an ambitious climate treaty, thereby reflecting the attitudes of Democratic and Republican senators towards climate change mitigation.

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[10] International treaties necessarily require the Senate's consent. Implementing climate policies only domestically could also be achieved through executive agreements. However, (international) treaties are found to be longer lasting than executive agreements (Nyarko, 2019). Hence the games presuppose international treaties instead of domestic executive agreements for effective climate change mitigation.

[11] The 118th Congress (2023-2025) consists of 48 Democratic, 49 Republican and 3 Independent senators.

4.4 The extensive treaty game of the USA

A bespoke game (*Fig. 2*) can now be employed to represent the two levels and the players' preferences that characterise the USA's climate governance. The president has the option to pursue one of four hypothetical treaties. These will vary in their proposed abatement goals for the countries and are ranked from 1 = very unambitious to 4 = very ambitious and represent game-theoretical strategies. The Senate can then ratify the treaty (*R*) or abstain from doing so (~~*R*~~).

The extensive treaty game of the USA

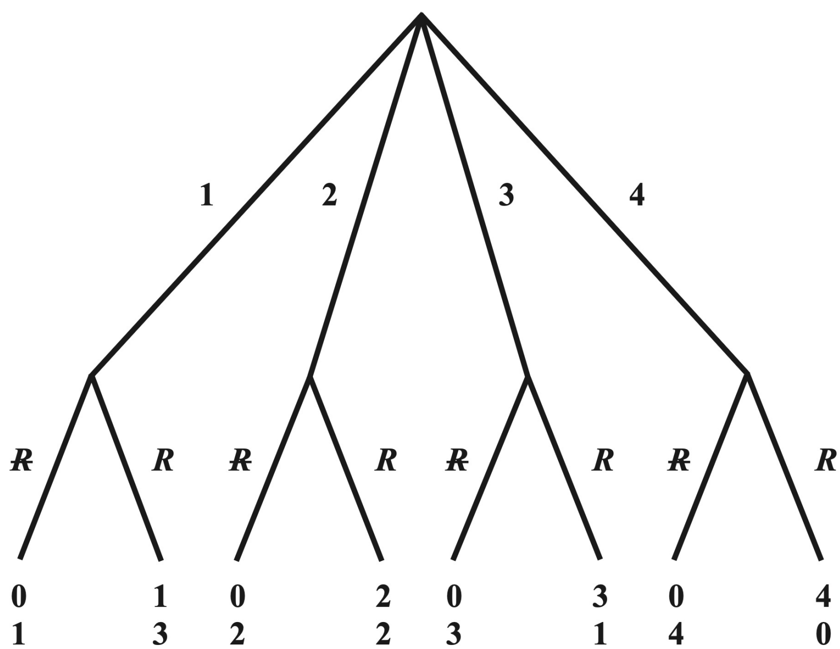

Fig. 2, USA's treaty game – own model

An extensive form game is used to demonstrate the sequential nature of the two levels for the climate strategy analysis of the USA. Extensive games are characterised by choice nodes, branches and terminal nodes with payoffs (Mesquita, 2009). Choice nodes denote points in the game where the players have to choose a strategy, e.g., the negotiator of the president opting for a particular climate treaty (1 - 4). The branches connect choice nodes with other choice nodes or terminal nodes. The latter signifies the end of a sequence in the game, such as the Senate ratifying treaty 3.

Each terminal node and its preceding branches ultimately represent a strategy profile with payoffs for the players (noted in chronological order).

The payoffs in the game are assigned values between 0 and 4, representing the players' preferences over the possible outcomes, with 4 being the highest preference and 0 indicating the lowest preference. The game is designed to reflect the discussed preferences, whereby a ratified, very ambitious climate treaty may procure the highest payoff for the president. Conversely, the lower the ambition of a ratified treaty, the lower the negotiator's possible payoffs. An unratified treaty (ambitious or unambitious) yields no payoff at all. For the Senate as a whole, on the other hand, refusing to ratify an ambitious treaty would lead to higher payoffs than ratifying such a proposal due to the discussed preferences. Only for unambitious climate treaties 1 and 2 would the average senator's payoffs for the outcome of choosing *R* be higher or equal to choosing ~~*R*~~.

4.5 Solving the game with backward induction

The game can now be solved for the determined payoffs with the game-theoretical methodology of backward induction. To apply this methodology, the concept of subgame perfection is required, more specifically, the subgame perfect Nash equilibria. For subgame perfection, players find their best response at a choice node based on their expectations of the other players' subsequent moves. How a player reaches a certain node is irrelevant to subgame perfection; it is about what every player would choose at every (hypothetical) node (Mesquita, 2009). The subgame perfect Nash equilibrium (SPNE) is a strategy profile that is the Nash equilibrium, i.e., best response to the other player in every subgame. Each Nash equilibrium found through backward induction is also a SPNE (Webb, 2007). Thus, extensive games can be solved backwards by starting from the terminal nodes and moving back to the first decision nodes.

In the extensive treaty game of the USA, not ratifying the (ambitious) treaties 3 and 4 is the subgame perfect strategy for the Senate at the domestic level because the payoffs for the outcome of ratification are lower than for non-ratification ($4 > 0$, $3 > 1$). For the unambitious treaties 1 and 2, ratifying the treaty results in higher or equal payoffs for the Senate than no ratifying ($3 > 1$, $2 \geq 2$). Consequentially, for the negotiator of the president, treaties 1-4 will have payoffs of 1, 2, 0, and 0 due to the expected decisions at the domestic level. Therefore, the SPNE proposes the president's choice for treaty 2, and the potential domestic ratification of treaties 1 and 2 as the game's solution.[12]

4.6 Results and implications

As a result, the game implies that the rational climate strategy for the president is to internationally endorse an unambitious treaty when contemplating ratification at the domestic level and the prevailing viewpoints of Republicans in the USA. A more ambitious treaty would fail to achieve the necessary approval by both Democrats and Republicans. Moreover, opting for an unambitious treaty would still be favourable to the president compared to an ambitious unratified treaty, i.e., no treaty at all (2 > 0).

In general, an ambitious treaty that results in higher emissions abatement is better for the whole planet than an unambitious treaty. However, the domestic situation in the USA and other countries with similar dispositions incentivise governments to refrain from supporting ambitious treaties and, thus, greater cooperation at the international level. This is yet another example of where individual self-interest (of some policymakers) hinders collective action. In particular, the fear of losing votes by supporting climate change mitigation among the Republican senators jeopardises cooperation at the international level as the president cannot promote ambitious climate treaties that would also be ratified. This two-stage game highlights the importance of social support, especially from voters for (international) climate governance. As such, addressing Republican senators in the USA and persuading them to support climate change could benefit international climate cooperation by increasing the likelihood that ambitious climate treaties are ratified.

4.7 Tackling missing climate action at the domestic level

As identified in the extensive treaty game of the USA, lacking support from Republican senators and voters for environmental measures may exacerbate the collective action problem in international climate governance. Consequently, prospective remedies should focus on enhancing awareness of climate change and promoting acceptance of climate action.

Various possibilities for increasing climate change awareness have been explored in the literature. Given that children and young people will be most affected by climate change in the future,

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[12] More specifically, treaty 2 has a ratification probability of 50% as the payoff for the respective strategy profiles of R and $\not{R}$ for the unambitious treaty are equal (2=2).

climate education in schools or community groups focusing on active citizenship could be one fruitful approach to more climate consciousness. This would have the added benefit of promoting intergenerational justice by emphasising the involvement of children in long-term issues such as climate change mitigation (Sanson & Burke, 2020). To counteract misinformation about climate change, measures can be taken to reduce its acceptance and raise climate awareness. For instance, conveying high-level expert consensus and pre-emptively warning people about intentional misinformation, which is often politically motivated, are effective measures (Van Der Linden et al., 2017).

Evidently, raising awareness through schools, local authorities, or NGOs in the USA about climate change and its consequences will be essential to convince more people about climate action. With enough support, particularly from Republican senators, ambitious climate treaties could have a chance to be ratified at the domestic level, with the potential to contribute to international climate action. However, it is unlikely that raising awareness and climate education alone will be sufficient to gain support among Republicans, given the polarisation between the parties and the initial low levels of climate awareness. Thus, an alternative approach must be sought to enhance the consensus between conservative and progressive factions of society and promote collective climate action in the USA.

4.8 The influential relationship between the international and domestic level

While the extensive treaty game primarily focused on domestic factors such as the ratification of treaties, examining the relationship between the international and domestic levels is essential. The influence of the international level and the domestic level work in both directions and can impact treaty ratification and, thus, cooperation in climate action. This influential relationship will be examined next.

First, the influence of the domestic level on the international level will be analysed, beginning with several *solutions*. One of the proposed ideas is a synergistic linkage between the opposing domestic camps, where a policy option or international treaty addresses issues previously outside domestic control, thereby gaining the support of both sides (Putnam, 1988). The Republican aversion to emissions abatement is rooted in concerns about economic decline, a loss of energy independence, and the USA's sovereignty (Leggett, 2021). Thus, a climate treaty at the international level, such as one with allied European countries but excluding China as direct competition, could potentially stimulate energy independence in the USA and thereby gain approval from both domestic camps. For instance, trade agreements on renewable energies that offer benefits only to treaty members could be considered. Whether, however, enough support can be reached at the domestic level with synergistic linkage for this *solution* to work remains unclear. Besides, while the initial exclusion of members in a treaty might increase some collective action, it obstructs the goal of *universal* collective action for the environment.

Moreover, the constraints of the USA at the domestic level can provide the president with increased bargaining power at the international level when other countries propose a treaty (Kroll & Shogren, 2008). The underlying idea is that other countries have to acknowledge the limited flexibility of the constrained country if a treaty or international cooperation is to realise. Consequently, the USA could use its enhanced bargaining power to secure extra conditions in an (ambitious) climate treaty that would appeal to Republicans, such as extended transition periods for the shift from coal to renewable energies.

Empirical evidence suggests a similar tendency for bilateral treaties: dovish governments possess greater negotiation power than hawkish governments, as international adversaries prefer to deal with the former in future (Clare, 2014). If applied to the domestic situation of the USA, opponents in the international arena would prefer to form a climate treaty with a Democratic government that is open to abatement measures *now*, in contrast to a Republican government that opposes climate action *later*. However, Kroll and Shogren find that the chances for such bargaining advantages in treaty negotiations decrease as the perceived international position of the USA strengthens (2008). In addition, it is again uncertain whether the concessions made by other players in this *solution* would suffice to convince Republican senators to ratify an international climate treaty.

Secondly, the international level can influence the domestic level to achieve more collective action. According to Putnam, the impact of international pressure can, for instance, facilitate agreement at the domestic level (Putnam, 1988). Hence, NGOs or governments could emphasise the significance of climate action from the USA and its global implications. This added international pressure could lead to increased domestic support for climate action and, thus, more ambitious climate treaties at the international level. In parallel, states can increase the chance of (treaty) ratification in the USA with policies that specifically benefit significant domestic players, as demonstrated in studies on environmental and automobile standards (Baccini & Urpelainen, 2014). The

US Chamber of Commerce is an example of a pivotal domestic player which could be nudged to support climate action with the help of concessions in an international treaty. This *solution* may consist of similar measures as the previous results of the additional bargaining power for the USA but with other states as the primary negotiators. Nonetheless, the same problem can arise: there are limits to how far exceptions and concessions in the treaty for domestic ratification in the USA are accepted by other countries. Otherwise, the level of ambition in the international climate treaty would reduce and could be perceived as unfair by other signatories.

In light of the domestic constraints of the USA, it is worth exploring what would happen if the USA were excluded from climate treaty negotiations. The research (Milewicz & Snidal, 2016) shows that multilateral powers may be incentivised to extend international cooperation even without American leadership as the increased influence in shaping the treaties furthers the chances of their domestic ratification. This, in turn, may incentivise the USA to reduce its domestic constraints to regain control and leadership by joining and ratifying the climate treaty.[13] Hence, in the long run, a climate treaty without American leadership could prove to be a viable *solution* for more collective action if domestic constraints can be mitigated.

To summarise, the discussed *solutions* for more climate action in the USA aim at improving support among Republicans, thereby increasing the likelihood that an ambitious climate treaty may be ratified in the Senate. The *solutions* encompass education, concessions in the treaty or benefits for pivotal domestic players, all seeking to alleviate the domestic constraint of the USA and mitigate the collective action problem in international climate governance. Nonetheless, no *solution* proves entirely satisfactory in the short term due to significant uncertainties regarding effectiveness. Thus, further research is necessary to find additional ways of addressing the USA's domestic constraints.

[13] More specifically, if a great number of signatory countries can render an international climate treaty very influential, Republicans would likely switch to supporting the treaty to safeguard the competitiveness and sovereignty of the USA.

5 India's emissions game with continuous strategies

5.1 Economic growth and vulnerability to climate change as determinants

India is another significant polluter and the next country which will be analysed with regard to its climate governance. The country's approach to mitigating climate change is expected to be influenced by two primary factors: the aim of economic growth and a high vulnerability to the impacts of climate change.

India's pursuit of economic growth is crucial to improve the living standards of its population, given a considerably lower GDP per capita than China or the USA. To effectively combat poverty and cope with demographic changes, new non-farm jobs for 90 million workers by 2030 have to be created, requiring an 8.0 - 8.5 % annual GDP growth, according to McKinsey & Company (Sankhe et al., 2020). On the other hand, it is vital to weigh India's economic growth against the negative impacts of climate change, which are exacerbated by additional CO_2 emissions. According to the Global Climate Risk Index 2021, which assesses what countries are most affected by extreme weather events, India ranked as the 7th most vulnerable country in 2019 (5th in 2018) with damages of 68$ bn in Purchasing Power Parity due to floods caused by heavy rains and tropical cyclones (Eckstein et al., 2021). Conversely, China and the USA have a significantly lower vulnerability to climate risks (*ND-GAIN Country Index*, 2023). With economic growth on the one side and exposure to climate change impacts on the other side, India will have to consider both factors when deciding on their climate strategies. This duality between economic growth and vulnerability to climate risks may further be intensified by ongoing reallocations of foreign direct investment (FDI) from China to India's economy (Whiteaker, 2022). Additionally, India, as country with the largest population, may require increased protection for its rising population from climate hazards.

5.2 India's global emissions game

The emerging game representing India's climate governance is hence a global emissions game (F1). In this, India seeks to maximise its emissions (economic growth)[14] while also aiming to

[14] Coal is e.g., responsible for 70% of energy production and crucial for India's economy, which is why large amounts of coal are currently imported to India and new mines are in the planning (Vaidyanathan, 2021).

minimise the damage caused by global emissions, to which India contributes through their own emissions:

India's global emissions game

$$\pi_i(e_i, e_g) = \alpha_i(e_i) - \beta_i(e_g) \tag{F1}$$

adapted from (Heugues, 2013; Wood, 2011)

Although in the form of a mathematical function, the essential elements of a game-theoretic model are still given. The necessary payoffs π_i of India reflect the outcomes of strategies India and all other countries can choose. The possible strategies in this context correspond to a particular CO_2 emissions level (e_i) pursued by India and the globally emitted level (e_g), respectively. Notably, the emissions of India are included in e_g, which complicates the calculations but accounts for India's significant share of global emissions, which amounts to 7%. A unique strategy for this game-theoretic model is the continuous space of strategies which implies that the players have infinite options to choose from, namely any emissions level that satisfies $e \geq 0$ (Heugues, 2013). As a result, this game differs from the others as it has unlimited players and unlimited strategies, i.e., emission levels.[15] For India, emissions level (e_i^*) generates the highest payoff π_i^*. Furthermore, α_i represents the emissions benefit function and β_i the emissions damage function of India. The properties of their derivatives are crucial for solving and interpreting India's emission game.

5.3 The properties and solution of the game

The assumption made is that the first derivative of α_i and β_i are positive ($\alpha_i' > 0,\ \beta_i' > 0$), which implies that benefit and damage functions are increasing with extra emissions (Finus, 2001). Thus, the more India pollutes, the greater the possible (economic) payoffs. However, as global emissions increase, the negative impact on climate and the environment also rises, leading to an overall decline in payoffs. The functions α_i and β_i differ in their second derivative. Whereas the marginal benefits decrease with emissions ($\alpha_i'' < 0$), the marginal damage increases with more emissions

[15] In practice the number of players (n) is limited by the emitting countries and the continuous strategy space restricted by negative emissions and unrealistically high emissions of individual countries.

($\beta_i'' > 0$) (Wood, 2011). The concave shape of the former reflects the standard assumption of decreasing marginal utility of production (Finus, 2001). At the same time, the convex form of the latter arises from the decreasing abilities of environmental systems to restore themselves, which in turn multiplies the damage caused by more emissions (Heugues, 2013).[16]

Reverting to the solution of India's emissions game, the Nash equilibrium requires a strategy for India to be the best response to the other players' strategies, namely the other's emissions levels. Thus, (F1) is differentiated with respect to e_i and is maximised when it is equivalent to 0:

$$\frac{\partial \pi_i}{\partial e_i} = 0 \tag{F2}$$

As Wood explains, the Nash equilibrium with its mutually best responses to the other players, viz. India (*i*) and every polluting country aggregated (*g*) yields a suboptimal solution: the rational strategy entails emissions reduction to alleviate the damage caused by emissions, but these reductions are *lower* than the socially optimal solution (2011).

Additionally, a more detailed examination of the properties of the derivatives reveals an obstructive dynamic. By employing the implicit function theorem for the derivation of π_i with respect to e_i, (F3) is obtained, indicating the consequences for e_i of a change in e_g (Wood, 2011, p.156).

$$\frac{de_i}{de_g} = \frac{\beta_i''}{\alpha_i'' - \beta_i''} \tag{F3}$$

adapted from (Finus, 2001, p.126; Wood, 2011, p.156), the derivation of (F3) is found in Appendix no. 1.

[16] Alternatively, the benefit function can be conceptualised as the opportunity cost of abatement, which rise with an increasing rate for more reduced emissions due to the need for increasingly expensive abatement technologies; the damage function can also be portrayed as the willingness of society to pay for abatement, which declines more than proportionally when the environment is enhanced through reduced emissions (Finus, 2001).

5.4 Interpreting the results

(F3) implies that India is incentivised to *increase* their emissions in response to a potential reduction of emissions (e_g), e.g., by a global polluter such as the EU due to $\beta_i'' > 0$ and $\alpha_i'' < 0$ (Wood, 2011). Therefore, India and countries with a similar disposition may rationally seek to take advantage of any beneficial emissions reduction of other countries and increase their own emissions in order to maximise payoffs and reach a new Nash equilibrium. This unsatisfactory rational answer of India to global emissions underscores again the collective action problem in climate governance, where the individual self-interest of India threatens collective abatement action. What is more, the game-theoretic model reveals how the collective action problem can consist of forces directly opposing any good intentions for cooperation. This is because the attempts of countries' cooperation to reduce emissions are likely exploited by the subsequent emissions increase of other countries, such as India, in the global emissions game. Consequently, cooperation in international climate governance is difficult to achieve in the first place and challenging to sustain.

Hence, India's emissions game highlights two issues that must be addressed to improve international climate governance. Firstly, in the present, the Nash equilibrium of (F1) results in lower CO_2 emissions than would be socially optimal. Secondly, future abatement efforts of some countries are likely to be thwarted by other countries that increase their emissions, thereby undermining the global goal of lower CO_2 levels.

5.5 Using a deposit mechanism for optimal abatement

In the collective action problem faced by India, two proposed *solutions* aim to reach socially optimal abatements levels of all players and to diminish players' incentives to increase their emissions subsequently. They can be divided into two categories: the first explores a *solution* without strong institutions, whereas the second relies on some levels of central authority.

To enhance collective climate action in India, the first potential *solution* requires a deposit mechanism for the players. By initially paying a deposit, players indicate that they are willing to reduce their emissions to socially optimal levels; these deposits are only refunded if they stick with their commitments (Gerber & Wichardt, 2009). Thus, the players would have incentives to abate the socially optimal amount and no incentives to free-ride and exploit abating countries since, otherwise, their deposits would not be refunded as a consequence. Gerber and Wichardt further argue that the deposits should be repaid immediately if not enough players commit to the collective goal in the initial stage (2009). Thereby, the deposit mechanism would be voluntary and would not cause a disadvantage to countries if there is a lack of overall motivation and contribution to the collective goal. Furthermore, the deposits would serve as a self-sanctioning scheme, and free riders would not have to be punished by others or central authorities (Wood, 2011). Nevertheless, the deposit mechanism would require some form of organisation, such as the UNFCCC or the World Bank, to collect and refund the deposits, as well as an independent auditor to determine the adequacy of the countries' abatements efforts. In practice, the deposits for India and other willing countries should depend on a country's wealth to represent a proportionate loss and discourage free riding. For example, the deposit could be set at 2% of the annual GDP and for a fixed period, such as one year, after which the deposit mechanism could be renewed by adjusting the deposit amount to reflect the new GDP share.[17] One drawback to this *solution* is that it would require many players to commit to the collective goal of abatement for it to be successful. Otherwise, other countries outside the deposit mechanism would have incentives to free-ride as they have no deposit to lose. To address this issue, the role of reputation (as discussed in 3.7) could perhaps assist in convincing countries to contribute to the collective goal by paying the necessary deposit. Alternatively, measures could be implemented to penalise free riders outside the deposit mechanism, a possibility that will be further explored in the following section.

5.6 Climate Clubs as a *solution* against the collective action problem

Another *solution* to foster climate action in India and other countries could be the implementation of so-called Climate Clubs, as proposed by William Nordhaus. A Climate Club would entail an agreement by the participating countries for which principal conditions must apply. It must include a sharable public-good-type resource; it must be beneficial for all members; the exclusion or penalisation of non-members must be possible and take the form of a stable membership in which no participating country wants to leave the club (Nordhaus, 2015).

The Climate Clubs aim to reduce CO_2 emissions globally, thus contributing to more collective climate action. For this, Nordhaus proposes an international target carbon price instead of fixed emission quantities, making abatement negotiations easier and letting the countries choose their national policies, such as carbon taxes or cap-and-trade mechanisms (2020). Thus, countries are

[17] Since the countries' deposits would likely be financed through government debt, the incentive to abate increases. This is because regaining the deposit is crucial to amortise debt and thereby preserve creditworthiness and reputation.

incentivised to find optimal abatement measures and complex mediation about particular abatement levels is avoided. The penalisation of non-members as the key concept would distinguish the Climate Clubs from current climate treaties, such as the Paris Climate Agreement. Uniform tariffs on imports of the non-members have been proposed to procure strong incentives for countries to join the club and avoid economic pain of tariffs (Nordhaus, 2020). This would encourage countries to aim at reducing socially optimal emission levels as determined by the carbon price. Additionally, there would have to be incentives for club members to refrain from free-riding, i.e., leaving the club. In this regard, the losses incurred through tariffs (for free-riders) would need to exceed the abatement costs of the club members (Nordhaus, 2020). Nordhaus suggests that a carbon price of 25$ and import tariffs of 3% for non-members would suffice as a necessary incentive for all 15 global regions studied, including India, to remain in the Climate Club (2015).

In contrast to the earlier *solution*, Climate Clubs would require a central authority to evaluate the countries' abatement efforts and ensure that the penalising tariffs are imposed. The effectiveness of such an authority is crucial as the *solution* with Climate Clubs hinges on the successful penalisation of free riders. However, it remains unclear whether such Climate Clubs along with the according authorities, are (legally) enforceable and how they would relate to the non-sanctioning UNFCCC or Paris Climate Agreement (Falkner et al., 2021).

Overall, the two discussed *solutions* to address the collective action problem of India, namely a deposit mechanism and Climate Clubs, have the potential to incentivise countries to abate socially optimal CO_2 levels and prevent subsequent free-riding. However, there exists a trade-off between free-riders and central authorities: a greater central authority, which is more difficult to enforce, can better mitigate free-riding (Climate Clubs), whereas abatement measures without strong institutions might be easier to implement but may not be as effective in addressing free riders (deposit mechanism). Furthermore, both *solutions* can be applied to other countries beyond India, which will be further elaborated in Chapter 7.3.

6 A model of climate cooperation within the EU

6.1 Climate cooperation in the EU

This chapter will examine the countries of the European Union (EU) that constitute around 7% of global CO_2 emissions. Unlike the previous countries, the EU displays unique characteristics that require further exploration. Precisely, the EU consists of 27 member states with varying sizes and economic powers, each with a different attitude towards climate change mitigation efforts. These individual attitudes are particularly vital for analysing climate governance in the EU as they significantly influence European climate cooperation.

Primarily, the EU member states exhibit a high level of cooperation. The EU's emissions trading system (ETS), as the biggest carbon market worldwide, exemplifies this climate cooperation as well as the binding emissions reductions for the member states (Verma & Chestney, 2023). In addition, the EU's Climate Target Plan 2030 aims to reduce greenhouse gas emissions to 55% compared with 1990 levels by 2030 and pursues climate neutrality by 2050, surpassing the ambitions of China, the USA and India (*2030 Climate Target Plan*, 2021).

Besides its effect on climate change mitigation, the EU's climate cooperation could serve another purpose. If the cooperation proves to be sustainable and enduring, it could nudge other countries to follow the example of the EU and collaborate together, e.g., by establishing a binding treaty for mutual emissions abatement.

However, any disparities and disproportionalities regarding expenses and benefits among the member states could impede this positive influence of the EU as a role model. In such a scenario, countries within and outside the EU would conclude that their self-interest could be harmed in the long run without appropriate and equal reward for abatement efforts. Consequently, countries may find that their climate commitments are undermined by the free riding of other countries that benefit disproportionally from collective abatement, rendering the cooperation unfavourable. Thus, this analysis will mainly focus on potential disproportionality concerning efforts and benefits in the EU's climate cooperation. For this, the individual attitudes of EU members towards mitigation efforts that are crucial for the EU's climate governance are explored next.

6.2 The EU members' attitudes and costs concerning climate action

To assess the attitudes of individual member states towards climate change mitigation, it may be beneficial to examine their past contributions to emissions abatement. These can indicate that a country places value on emissions reduction outcomes, such as the prevention of floods or droughts. According to Dennison et al., Sweden, Finland, and Denmark have made the most progress regarding the shift to renewable energies, while the Netherlands, Luxembourg and Poland have lagged behind (2021). Similarly, when considering the priority of climate action in the EU, Belgium, Sweden, Finland, and Denmark prioritise climate action the most, in contrast to Poland which opposed the European Green Deal in the negotiations or Bulgaria and Romania, which appear to refrain from implementing the EU's climate policies (Loss, 2020; Dennison et al., 2021). The research (Biedenkopf, 2021) suggests that the opposition to the European Green Deal and climate action may stem from the polarisation of political parties and concerns that emissions reduction efforts may harm economic competitiveness. Overall, it is apparent that the member states can be divided into an ambitious group that values climate change mitigation highly and an unambitious group that prefers lower mitigation efforts.

It is further assumed that all players bear the same costs of additional emissions reductions. This assumption is underpinned by the European Emissions trading system, which enables cost-effective emission abatement across the EU (*EU Emissions Trading System (EU ETS)*, 2021). Additionally, the Green Deal's Just Transition Fund supports areas that lack the necessary infrastructure and capacities to efficiently reduce emissions, thereby mitigating higher costs in these regions (*Contribution to the Green Deal and the Just Transition Scheme*, 2020).

6.3 Constructing a new model for the EU member states

In the following section, I will develop a game-theoretic model to depict the different perspectives on emissions reductions held by the member states and analyse the implications of these attitudes for climate cooperation in the EU. To construct this model, I will draw upon the NATO defence problem presented in the salient essay "An Economic Theory of Alliances" by Mancur Olson and Richard Zeckhauser (1966). The authors show that in significant alliances such as NATO, larger nations contribute disproportionately more towards the common good of defence than smaller nations due to varying evaluations of the nations (Olson & Zeckhauser, 1966).

The next model (*Fig. 3*) transfers the NATO defence problem to the scenario of abatement efforts of EU member states. Although presented in a different format than before, the model comprises the three game-theoretical elements: players, strategies and payoffs. Beginning with the former, there will be two players denoted as H and L, representing the two aforementioned groups of member states with contrasting attitudes to additional emissions abatement. Player H evaluates additional abatement highly (H), while (L) places a lower value on emissions reduction.

The players' strategies are found on the x-axis (Additional Emissions Reduction in tCO2e). Moving towards the right implies more additionally abated emissions by a player, where the reduced emissions of a group's countries are consolidated. The Efforts Sharing Regulation by the EU binds members to obligatory annual emissions reduction (*Effort Sharing: Member States' Emission Targets*, 2021). Thus, only *additional* emissions reductions are considered as strategies to reveal how the varying climate change attitudes of the countries influence their (extra) contributions to climate action.

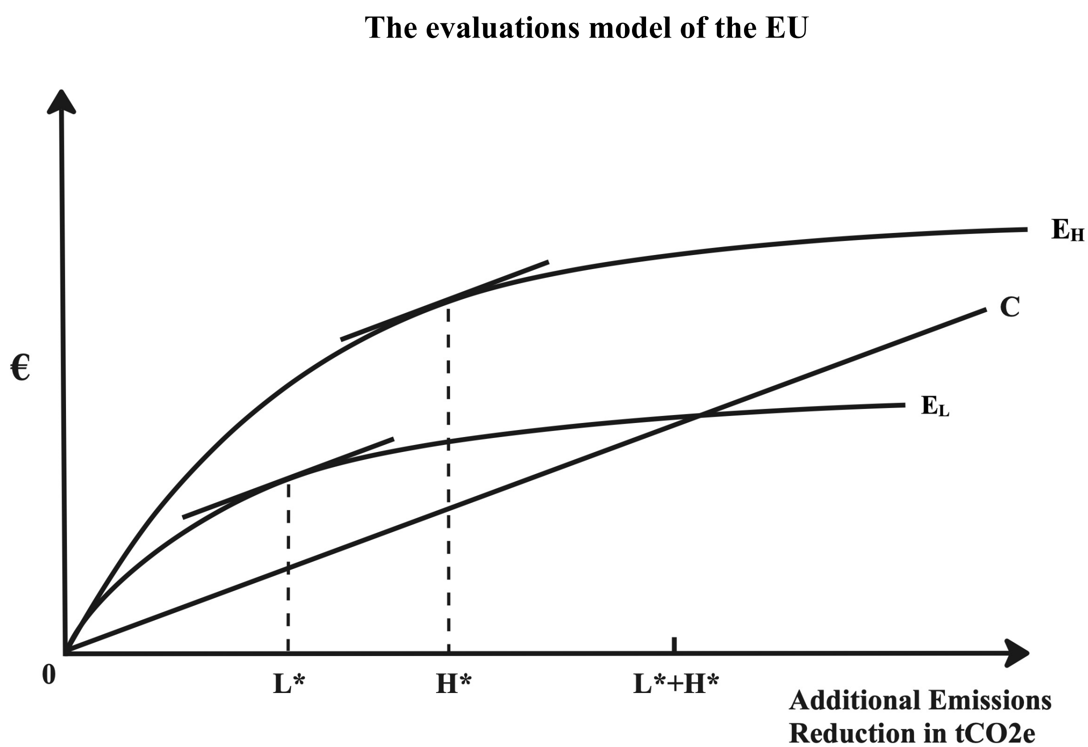

Fig. 3, EU's cooperation model - own model based on the NATO defence problem (Olson & Zeckhauser, 1966, p. 269)

The payoffs of the game-theoretic model are less visible. They are determined by the players' evaluation of climate action and the cost of additional emission abatement. Here, the evaluations of emissions reductions by players L and H are represented by E_L and E_H, respectively, and measured in Euro per reduced tCO2e (y-axis). The curves are assumed monotonically decreasing due to the diminishing marginal utility of emissions reductions. The constant costs of additional emissions reduction are denoted as C. To determine the payoff for specific levels of tCO2e, the values of the cost curve must be subtracted from the corresponding values of the evaluation curve(s).

6.4 Maximising the player's payoffs

To find the optimal strategies for the two players, i.e., the solution of the game, it is necessary to maximise the payoffs. Two scenarios can be considered for this.

If the players maximise their payoffs *independently*, the emissions levels at L* and H* for L and H, respectively, will result in the highest payoff. At these levels, the evaluation curves are parallel to the cost curves, indicating the greatest difference between them and, thus, the highest payoff. Under this scenario, the total additional abatement would equal the sum L*+H*. Since L* and H* represent Pareto-efficient solutions ($E_L' = C' = E_H'$), the sum L*+H* would represent the socially optimal outcome.

In contrast, when the two players make their choices *simultaneously*, they face higher marginal costs than marginal benefits at L*+H* as they now include the other player's abatement in their maximisation. This more realistic example results in H only abating as much as H* and L not reducing any additional emissions (cf. the NATO defence problem). The reason for the change from L* to 0 abated emissions is L's benefits from H's abatement at H*. At this level, the marginal costs of further emissions reductions for L exceed their marginal benefits, as indicated by the shallower slope of E_L compared to C at H*. The next step discusses the implications of this realistic scenario.

6.5 Implications of the model

Overall, the game-theoretic model suggests that disproportionality arises between the two groups of member states, with some countries (H) abating additional emissions that also benefit those countries (L) that do not reduce additional emissions due to differences in their attitude to climate action. As a consequence, the overall abatement achieved (H*) is lower than the socially optimal outcome of L*+H*,

Particularly, the potential disproportionality between ambitious and unambitious EU members in climate governance could jeopardise cooperation and collective action in the EU. The ambitious member states (H) may feel deceived by the inaction of the unambitious countries (L) and question the full commitment of all member states to the collective goal of climate action in the EU. As a result, tensions between member states may deteriorate, particularly in debates and disputes surrounding nuclear energy (see, e.g. Abnet & Gray, 2023) or vehicles with combustion engines (see, e.g. Chazan & Hancock, 2023). Hence, the individual interests and attitudes to emission reductions of some member states and the possible disproportionality have the potential to generate a collective action problem in the EU's climate governance. Moreover, the disproportionality could undermine the positive influence of the EU's climate cooperation on other non-European countries, as the cooperation could be viewed as unfavourable and thus unstable.

6.6 Improving European climate action through a cost-sharing scheme

A *solution* to the possible problem of potential disproportionality within climate action of EU members would be to adopt a marginal cost-sharing scheme, as proposed by Olson and Zeckhauser for the NATO defence problem (1966). The underlying idea here is to align abatement efforts and benefit of the EU countries so that "there were an arrangement such that the alliance members shared marginal costs in the same proportions in which they shared additional benefit" (Olson & Zeckhauser, 1966, p. 271). Thus, disproportionality could be eliminated as the EU members would contribute to the public good, i.e., additionally reduced emissions. Furthermore, this approach addressed disproportionality in such a way that free riders are required to adjust and pay more rather than ambitious members having to reduce their abatement efforts less. The latter alternative would have a counterproductive impact on the global goal of combating climate change.

Two approaches for implementing a marginal cost-sharing scheme for the EU will be sketched briefly. They have in common that rather than imposing extra payments on the unambitious members, the ambitious members receive benefits for every additional emissions reduction. The costs associated with additional abatement efforts can be shared proportionally across the EU by creating this comparative disadvantage for the unambitious members.

The first approach already adopted in the European Effort Sharing Regulation, involves allowing member states to bank or sell any surplus of abated emissions beyond their annual emissions allocation (Peeters & Athanasiadou, 2020). Thus, ambitious members receive more flexibility in their abatement trajectory, and they have the opportunity for financial gains by selling their emission allocations.

A second proposal in light of a marginal-cost-sharing scheme would be to reward ambitious members with greater leadership in European climate policy, such as by creating an influential climate committee within the EU's decision-making bodies. By doing so, ambitious members would have an increased ability to shape climate policies for abatement trajectory towards climate neutrality. The ambitious members could ideally use their greater influence in European climate policy to implement new incentives for the unambitious members to increase their abatement efforts, e.g., through joint projects for developing abatement technologies. Similarly, in the NATO defence problem, free-riding was found to be less severe than predicted by the economic theory of alliance, likely due to the significant bargaining influence of the large countries that induced small countries to contribute more to collective action (Dall'Agnol & Dall'Agnol, 2020).

As the *solution* of the European Effort Sharing Regulation shows, the issue of disproportionality between European member's abatement efforts is already addressed by the European Union. Nevertheless, exploring other *solutions*, such as increasing the influence of ambitious member countries in the European climate policy, can further assist in mitigating the disproportionality of abatement efforts. This would enhance collective climate cooperation in the EU and could thereby encourage other non-European countries to cooperate more for combating climate change.

7 Conclusions

7.1 Summary

This thesis studied the climate governance of four major global players, namely China, the USA, India and the EU, with respect to potential collective action problems and attempts to mitigate free-riding and promote collective climate action.

First, China's possible climate strategies were analysed in two separate scenarios. The first scenario situated China in a bipolar structure alongside the USA. Using the Prisoner's Dilemma as an illustrative game, it was found that this situation likely results in a collective action problem where both countries avoid reducing emissions. This is due to the intense rivalry where the cost of abating emissions could jeopardise their economic competitiveness and global superpower status. The proposed attempts to incentive China to emissions abatement consist of measures to reduce China's relative gains and to create the scenario of an infinitely repeated Prisoner's Dilemma that could entail cooperation. However, the exacerbating relationship between China and the USA makes both solutions' feasibility unlikely. In the second scenario, China was considered in a multipolar structure. The emerging game-theoretic model demonstrated that China may only cooperate in abating emissions collectively if enough other countries also reduce their emissions due to positive externalities such as technological spillovers. Here, it became evident that status rewards, e.g., joint investments with other prominent players, could be a conceivable measure to stimulate China towards initial emissions abatement.

The USA faces a domestic constraint in its climate governance due to public polarisation regarding the same issue. An extensive game analysis revealed that this is a potential obstacle to the government's participation of the USA in an ambitious international climate treaty due to low chances of ratification in the Senate. To promote support for collective climate action in the USA, it is crucial to address the issue domestically and internationally. Domestically, raising climate awareness and counteracting misinformation could potentially motivate Republican Senators to support the domestic ratification of an ambitious climate treaty. Internationally, global players could increase the chances of the Senate's ratification through concessions in the treaty or benefits for pivotal domestic players in the USA. However, further research is necessary to explore additional measures to increase US support and ratification chances of an ambitious climate treaty.

In India's climate governance, the country's high vulnerability to climate risks and economic growth are critical factors. The global emissions game reflects these decisive factors. It indicates that overall, less than optimal emissions are abated, and additionally, India may have incentives to increase pollution if other countries expand their emissions reductions. In order to address this free-rider problem, the thesis proposed two approaches: a deposit mechanism to incentivise contributions to the collective good of emissions reduction and Climate Clubs that penalise free-riders. Comparing both approaches, the study found that the former is more feasible for it relies on a central authority to a smaller extent, but it may not address free-riding as effectively as the latter.

Lastly, the thesis examined the climate cooperation among the EU member states and their varying attitudes towards emissions abatement. With a game-theoretical model, it was demonstrated that these different evaluations could lead to disproportionality among the member states regarding additionally abated emissions. This situation may further increase tensions in the European climate discourse and undermine the positive impact of European climate cooperation on non-European countries. To address this issue of collective action, a marginal cost-sharing scheme was proposed to distribute efforts and benefits of the EU member more equally. More specifically, the scheme would reward extra abatement, thereby enhancing cooperation for emissions abatement in the EU. The European Effort Sharing Regulation already provides ambitious member states with increased flexibility for emissions allocations. Additionally, the formation of an influential climate committee comprising only ambitious member states could be seen as a reward for their extra emissions reductions. Consequently, unambitious EU members would be disadvantaged, and extra abatement costs would be shared more proportionally to improve European climate cooperation and its positive influence on non-European countries.

7.2 Limitations of the thesis

This thesis has four limitations concerning the game-theoretical approach and its assumptions. First, the assumption that players are rational and seek to maximise their utility may not always reflect reality. Emotions, biases, or other factors can influence the behaviour of actors, which is not accounted for in the discussed games. Secondly, perfect information is presupposed for the evaluation of the players' strategies in the games. However, in practice, imperfect information about payoffs or other actors' preferences can impact the decision-making process and affect the outcome of the games. Thirdly, assumptions to simplify the games including unitary actors as representative players (all games), a limited number of players (e.g., China versus the USA), solely two emissions strategies (abate and pollute), one-shot and simultaneous games (Prisoner's Dilemma), constant abatement costs (e.g., EU), and concave benefits and convex damage functions (India) may overlook various other factors relevant to the complex interactions of the players. Lastly, empirically observing the outcomes of games may only be feasible in specific cases, for example, through the annual Conferences of the Parties by the UNFCCC. Primarily, the possibility of testing the models is limited in practice. This may restrict their ability to predict international governance accurately. Overall, these limitations indicate that the explored game-theoretic models can provide merely approximate predictions about potential collective action problems as they cannot include *all* determining factors relevant to countries' climate strategies.

Despite these limitations, the models demonstrate that the different climate policies and environmental preferences of the discussed countries suggest *specific* collective action problems. Moreover, they contribute to the field by highlighting the importance of *individually* assessing countries' climate strategies for collective climate action. International politics is required to abstract the *determining* underlying factors and their crucial predictions from the complex political entanglements. After all, "one great benefit of studying game theory is developing the ability to abstract key strategic ingredients from a wide variety of interactions" (DeVos, 2016, p.134).

Therefore, simple but comprehensive models may help to inspire policymakers to decisive measures for climate action, thereby pointing the way to a sustainable future for the planet.

7.3 Discussion and outlook

The discussed climate strategies of the different countries and their distinct factors result in different game-theoretic models with unique implications. In practice, however, these critical factors are not exclusive to one country but can also be found in other countries. For instance, most countries require some form of domestic approval to join a climate treaty, which may be influenced by polarised opinions on climate action, as seen prominently in the USA. Furthermore, there might be intense economic rivalries between developing countries, for instance, that resemble the situation between the USA and China on a smaller scale. Similarly, many countries, especially insular states and developing countries, may face high vulnerability towards climate-induced hazards, as in the case of India. And within countries, federal states or municipalities could encounter the potential disproportionality between ambitious and unambitious members regarding climate change, as found within the EU. Consequently, the proposed solutions could also address other collective action problems of countries not examined in this thesis. Specifically, the deposit mechanism and the approach with Climate Clubs promote more climate action, with more countries paying deposits and more members in the clubs. Thus, by categorising countries according to typical climate governance factors, broad or even universal solutions, such as the Climate Clubs, could be identified.

This leads to the outlook that can be drawn from this thesis. To enhance global climate action in the long run, broad solutions are necessary to address many countries' collective action problems. To find these general measures, countries have to be analysed individually with respect to distinct factors in their climate governance. Only this allows the categorisation and comparison of countries and their climate issues to explore general *solutions* for more international climate cooperation. This thesis started to analyse four significant global players; however, more countries should be studied to provide the necessary comprehension of international climate governance for policymakers to create more comprehensive solutions for global climate cooperation.

8 List of Appendices

Appendix no. 1 (calculation): derivations for India's global emissions game (Finus, 2001, p.126; Wood, 2011, p. 156).

India's global emissions game:

$$\pi_i(e_i, e_g) = \alpha_i(e_i) - \beta_i(e_g) \tag{F1}$$

Differentiating (F1) with respect to e_i and obtaining the first-order conditions.

$$\frac{\partial \pi_i}{\partial e_i} = \alpha_i{}'(e_i) - \beta_i{}'(e_g) = 0 \tag{F2}$$

Taking the total derivative of (F2) by using the implicit function theorem and rearranging terms, one can derive (for $i \neq g$),

$$\underbrace{\left(\frac{\mathrm{dy}}{\mathrm{dx}} = -\frac{\frac{\partial \mathrm{f}}{\partial \mathrm{x}}}{\frac{\partial \mathrm{f}}{\partial \mathrm{y}}}\right)}_{\text{implicit function theorem}} \quad => \quad \frac{de_i}{de_g} = \frac{\overbrace{\beta_i{}''}^{>0}}{\underbrace{\alpha_i{}''}_{<0} - \underbrace{\beta_i{}''}_{>0}}. \tag{F3}$$

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