BACHELOR THESIS

Game Theory in International Climate Change Negotiations:

Why does the US plan to withdraw from the Paris Agreement and what are the consequences for countries and future climate protection?

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Statutory Declaration

I hereby declare that I have authored this thesis independently and I have not used other than the declared sources. To the best of my knowledge all used sources, information and quotations are referenced as such.

Date: 31.08.17 **Signature**_______________

Patricia Désirée Messner

Table of Content

List of Abbreviations

BASIC	Brazil, South Africa, India, China
CFC	Chlorofluorocarbon
CMP	Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol
COP	Conference of the Parties
CO2	Carbon dioxide
EU	European Union
GARP	Global Atmospheric Research Programme
GDP	Gross Domestic Product
ICSU	International Council for Science
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-Governmental Organization
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WMO	World Metrological Organization
WWW	World Weather Watch

Abstract

Climate change is one of the most challenging topics to the world and has been subject to international negotiations for more than 25 years, one of the main players being the USA. Game theory, on the other hand, is a popular tool from economics, frequently used to analyze strategic situations such as international negotiations. Together, the insights from these topics can help understand why the USA's president Donald Trump has announced to quit the Paris Agreement and which consequences this might have for the US, other countries and for the future of international climate change negotiations. In order to assess the different implications, this thesis gives some theoretical background and presents game theoretic findings on climate change negotiations. It will be found that, from a game theoretic point of view, different reasons might have caused the USA to take this decision and that there is a chance that a withdrawal of the US from the Paris Agreement could have some effect on the future of climate protection. However, a precise assessment would require further research on the topic.

Exposé

Relevance and goals

In today's and the last decades' international negotiations, climate change has always been amongst the most discussed topics. Apart from being affected by uncertainties and unpredictabilities concerning the impacts of today's climate-related decisions and behavior as well as the timely manner in which they will be noticeable, climate change negotiations are subject to numerous strategic challenges, as are all negotiations on common resources.

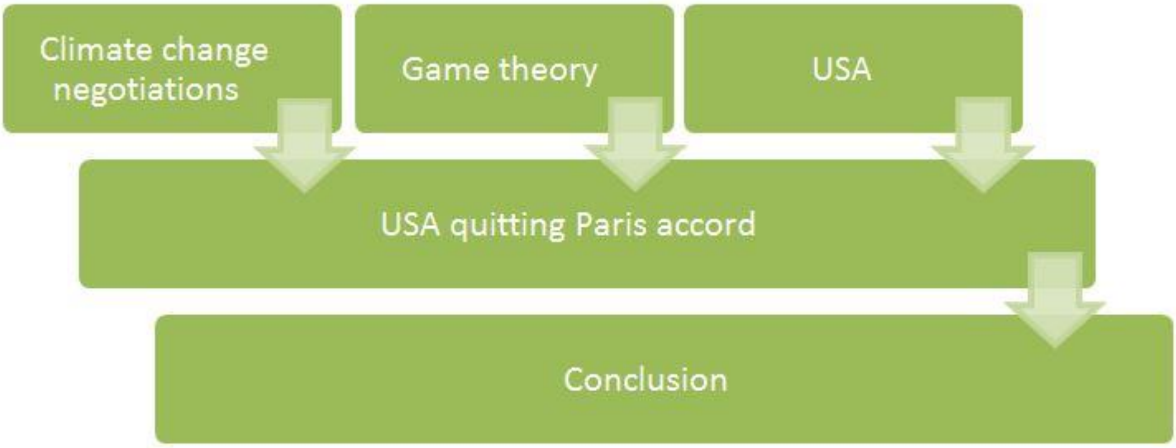
Having experienced a long history of conferences, debates and non-binding commitments, it is widely believed that climate change negotiations have come to a breakthrough through COP21, which took place in Paris in December 2015. However, the success of this accord is severely being put into question since the USA's president's statement from 1st June 2017, when Trump announced the USA's withdrawal from the agreement.

Considering the latter, this thesis aims to analyze the given situation and the strategic implications for the concerned parties and the future of climate protection, using basic game theoretic models and answering the following key questions:

Key questions

- What has COP21 achieved and what has still to be improved in international climate change negotiations?
- Which role does the US play in climate change and international climate change negotiations?
- How can game theory help understand and improve international climate change negotiations?
- How can game theory explain Trump’s decision to quit the Paris Agreement and the consequences for the countries and future climate change negotiations?

Methodology



In order to answer these questions, the first part of this thesis will provide the reader with some theoretical background information on the history of climate change negotiations until COP 21, the role of the USA in climate change and climate change negotiations and an introduction to game theory. In a second step, a broad review of game theoretic applications to the issue of international climate change negotiations will allow the reader to gain an understanding of how game theory can explain and even help to optimize strategic situations. The third part of the thesis will reunite the findings of the previous chapters in order to analyze the reasons why the USA might decide to quit the Paris Agreement and which consequences it could have. The last chapter will give an overall conclusion and present an outlook on further research that could be relevant to this topic.

Limits

Apart from the fact that game theory is only one tool to look at strategic situations, one of the major constraints when using game theoretic models is that on the one hand, it is desirable to include as many variables as possible in the models for the outcome to get as close to reality as possible. However, on the other hand, models should still be simple and clear enough to be solvable.

Another essential limit of game theory and therefore also this thesis is that game theory assumes certain conditions, such as the rationality and intelligence of the involved parties. Even though in international climate change negotiations the main players are countries or country unions, they are still represented by individuals that have their own interests and opinions in mind and therefore might not always take rational and long term oriented decisions.

Thus, the intention of this thesis is not to build a detailed and sophisticated game theoretic model and predict future actions and developments in climate change negotiations, but rather to give an overview of different game theoretic approaches that can be used to comprehend and analyze the given situation.

Theoretical Background

Chapter Outlook: The following chapter will give some background information on three topics relevant to this thesis. First of all, a historic overview of the history of international climate change negotiations until COP 21 will be given, followed by a presentation of the USA's position in climate change and climate change negotiations. Finally, an introduction to game theory will provide the reader with some basic concepts in order to allow him understand further game theoretic models.

1. International Climate Change Negotiations

1.1. History of International Climate Change Negotiations

1.1.1. Early History

After climatology had experienced a shift from being a descriptive to being a physical science due to five major developments in science, technology and geopolitics during the 1950s[1], the new opportunities for monitoring, predicting and even controlling climatic and weather developments provided to the WMO World Weather Watch (WWW) and the WMO/ICSU Global Atmospheric Research Programme (GARP)[2] soon raised concern that the rising concentrations of carbon dioxide in the earth's atmosphere could already have begun affecting climate developments[3].

[1] Flohn (1970), pp. 223-229
[2] Davies (1990)
[3] SMIC (1971)

Contrary opinions on climate change, ranging from global warming to global cooling, drew the UN's attention to the topic. In order to find out more about climate change and its consequences, the UN entrusted the WMO with a study of climate change which was executed by an Executive Committee Panel of Experts that came to the conclusion that greenhouse warming could be expected.[4] These findings encouraged the WMO to arrange the first World Climate Conference in Geneva in 1979 in collaboration with the UNESCO, the WHO, ICSU and other partners with various scientific backgrounds, such as agriculture, water resources, environment, ecology or economics[5]. Still it took further conferences in Villach, Toronto, Hague, Noordwijk and Geneva and the first assessment report of the IPCC, the discovery of the stratospheric ozone hole and the publication of the Brundtland Commission report "Our Common Future" until international political action was taken for the first time in 1992, when the United Nations Framework Convention on Climate Change (UNFCCC) with currently 197 participating parties, 157 of them having ratified the convention[6], was adopted[7].

1.1.2. Times of the Kyoto Protocol

The UNFCCC's goal is to stabilize greenhouse gas concentrations in the earth's atmosphere. After it had entered into force in 1994, the first attempt to agree upon legally binding targets for greenhouse gas emission reductions was made during the third Conference of the Parties (COP) to the UNFCCC in Kyoto, Japan, in December 1997, where ministers from 170 countries around the globe met and negotiated with the aim to make a first step towards more profound, stricter and international emission reduction commitments. The result of the conference was the Kyoto Protocol, which divided the participating countries into different groups and followed the principle of "common but differentiated responsibilities". This means that even though all nations have the responsibility to work against climate change, industrialized nations, as they are bearing historical responsibility, should demonstrate leadership in addressing climate issues. Therefore, the Kyoto Protocol ought the Annex I countries to reduce

[4] Gibbs et al. (1977), pp. 50-55
[5] White (1979)
[6] UNFCCC, official website
[7] WMO, official website

their emissions of the six major greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), measured in the respective CO_2 equivalent[8], by 5.2% in the period from 2008 to 2012, baseline level being 1990, while no legally binding mitigation targets were opposed on developing countries.[9]

As the USA considered the developing countries' special status to be unfair, the country withdrew, which made the European Union the main player for pushing the negotiations forward. However, in 1992, US President George H. W. Bush signed "hesitatingly and under pressure"[10] the UNFCCC, followed by President Clinton, who stated that the US would only agree upon binding emission reductions for developed countries if developing nations like India and China also took on responsibility and accepted binding commitments as well. Meanwhile, the EU aimed for an extensive accord including wide-ranging domestic action for Annex I nations without the flexibility mechanisms emissions trading, joint implementation and the clean development mechanism in order to reach a 15% reduction of greenhouse gas emissions.[11]

Even though the US refused to ratify the Kyoto Protocol and excluded itself from climate change negotiations as much as possible under the George W. Bush administration, the Kyoto Protocol still entered into force on 16 February 2005 when Russia ratified it and the accord met the requirement of a total ratification by countries representing 55% of global emissions.[12]

Two years later, in 2007, COP 13 and CMP 3 in Bali, Indonesia, took a new direction as for the first time, long-term issues were addressed. Finally, the Bali Action Plan and the Bali Roadmap were adopted. These should improve the negotiation process by separating two different working groups. [13] The first one, the Ad hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP) had already been established in Montreal during the CMP 1 with reference to the protocol's Article 3.9, which requires further

[8] For previous section see: UNFCCC, official website, Kyoto Protocol
[9] Bodansky (2001), pp. 23-39
[10] Roberts (2011)
[11] For previous section see: Hepburn (2007), pp. 375-394
[12] The Guardian (2015a)
[13] Ott (2008), pp. 91-95

commitments of Annex I countries at least seven years before the end of the commitment period.

The second one, the Ad hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) was newly established in Bali, having a focus on key elements of long-term cooperation, for instance mitigation, adaptation, finance, technology, and a shared vision for long-term cooperative action.[14]

1.1.3. Negotiations on a successor for the Kyoto Protocol

The COP 15 in Copenhagen in 2009 was widely conceived as a potential milestone in the history of international climate change negotiations and high expectations were raised as it was the deadline for agreeing upon a successor treaty to Kyoto. Apart from the hope for fundamental progress in the negotiations, which had been lacking the years before, the presidency of Barack Obama gave cause for optimism in terms of the USA's constructiveness and involvement. However, even though the US did indeed take a new course of action and actively participated in the Copenhagen negotiations, the resultant Copenhagen Accord was widely criticized and even perceived as a failure because goals were not achieved.[15]

Besides the fact that there was no consensus regarding a successor treaty to the Kyoto Protocol, the new Accord proposed a system of voluntary emission reductions instead of legally binding commitments, which led to tremendous criticism. In addition, many of the nations taking part and observers felt that the negotiation process was neither democratic nor transparent as the final decisions were taken spontaneously between the USA, Brazil, South Africa, India and China (BASIC) without including other parties such as the EU that was until then the driving force in international climate change negotiations. Therefore, the excluded party rather took note of the Copenhagen Accord than adopting it the way it had been done with the Kyoto Protocol.[16] Particular criticism was focusing on the fact that the two largest greenhouse gas emitting nations, China and the US with its additional historical responsibility, had not managed to set a good example and lead the negotiations together with all the

[14] UNFCCC, official website: Home
[15] For previous section see: BBC News: http://news.bbc.co.uk/2/hi/8426835.stm
[16] For previous section see: The Guardian (2009)

other participating nations towards a democratic and trendsetting multilateral agreement.[17]

In Cancun, Mexico, the next set of negotiations took place in December 2010 during the COP 16. Subsequent to the rather disappointing results of the Copenhagen Conference, expectations towards the summit were not particularly high. On the one hand, there was no success in finding a consensus on legally binding emission cuts. Furthermore, many important decisions had been delayed to the next round of conferences in Durban. Therefore, the outcomes of the Cancun negotiations were often described as a “weak deal”. [18] Nevertheless, progress could be observed in terms of how negotiations were held in comparison to the previous ones in Copenhagen, as dialogue between all parties was encouraged and transparency was kept up. Additionally, essential decisions had been taken, including the official recognition of the necessity to limit global warming to 2 degrees Celsius, providing assistance to developing nations in coping with climate change issues and launching several new bodies and processes. The latter comprise the Green Climate Fund which was meant to function as the operating unit of the Convention’s financials, the Technology Mechanism which is divided into the Technology Executive Committee and the Climate Technology Centre and Network and aims to enhance climate technology development and transferring it to developing nations[19], and the Cancun Adaptation Framework, stating that adaptation and mitigation should be addressed at the same priority level.[20]

During the following years’ COPs in Durban, Doha, Warsaw and Lima, a rulebook for the emission reduction from deforestation and degradation is finalized, a mechanism to cope with destructions from climate change is produced and the parties committed to elaborating a new universal climate change agreement by 2015.[21]

[17] Bodansky (2001), pp. 23-39
[18] The Guardian (2010)
[19] For previous section see: UNFCCC, official website, Technology Mechanism
[20] UNFCCC, official website, Timeline
[21] UNFCCC, official website, Timeline

1.2. COP 21

COP 21 that was held in Paris from 30 November to 11 December 2015 is widely perceived as a huge success as for the first time in the history of climate change negotiations, all countries in the world except for two managed to agree on a set of actions to tackle global warming and reduce greenhouse gas emissions.[22] The main elements of the accord include holding global warming compared to pre-industrialized levels at “well below” 2°C, preferably limiting temperature rise to 1.5°C. In order to achieve this, the agreement aims to decrease greenhouse gas emissions to the level that can be naturally absorbed, for instance through trees and soil, within the second half of the 21st century. To keep countries on track, a pledge and review system is established that requires the parties to make new pledges in five year intervals and reviews the countries’ proceedings. Additionally, industrial countries shall support developing nations through the provision of financial means, technologies and capacity-building.[23]

However, Rogelj et al. analyzed the effectivity of the countries’ INDCs and came to the conclusion that, even though minimizing greenhouse gas emissions, these individual contributions would collectively still lead to a global warming of 2.6°C to 3.1°C by the end of the 21st century. Even though this assessment does not take into account a gradual strengthening of scope and ambition of the INDCs, the researchers found that meeting the goal to hold global warming below 2°C would require action not only from the states but also from sub-national and other institutions.[24]

Bodansky on the other hand points out that the Paris Agreement can neither be perceived as a success for its content, nor for the sufficiency of the parties’ start off pledges. However, it might be justifiable calling the Paris accord a success if in the future it turns out to call up global action against temperature rise. Eight positive features of the agreement being pointed out include that it is in some areas legally binding, that in contrast to Kyoto the Paris Agreement is global, in that its requirements are not limited to industrial countries and that it stipulates some central obligations for all countries, which takes into consideration that a

[22] BBC (2017)
[23] For previous section see: United Nations (2015)
[24] For previous section see: Rogelj et al. (2016)

countries capacity and situation can change over time. In addition, the accord is considered to be constructed in a durable and continuous way as it involves making pledges repeatedly with increased commitment, which might lead to increasingly tougher actions against global warming. Finally, the agreement managed to achieve almost universal recognition and acceptance and led to something comparable to peer pressure through the increased transparency and accountability levels. For this reason, Bodansky concludes that it is not yet assessable whether the Paris accord will turn out to be as successful as sometimes suggested by the media. Yet, if it does, it will probably be based on the fact that it fosters awareness and hence encourages further negotiations.[25]

2. USA in Climate Change and Climate Change Negotiations

2.1. USA's Contribution to Climate Change

A country's contribution to climate change can be assessed in different ways. The results can differ dramatically depending on the approach being chosen and factors such as the comparison period, variables considered and comparison unit. Some approaches are applied to the USA in the following.

2.1.1. Total Emissions Approach

In 2016, the USA were the second largest producer of carbon dioxide emissions with 15.99% of total emissions, following China with 28.21% and contributing more than twice as much to global emissions than the third ranked nation India.[26] However, one essential point in climate change negotiations is to what extent developed countries bear more responsibility for global warming due to historic emissions than developing nations. Additionally, it has to be pointed out that direct carbon emissions are not the only driver of global warming. Other drivers include carbon dioxide emissions caused by changes in land use, such as agriculture and deforestation, greenhouse gas emissions other than carbon dioxide, for example methane, emissions that have a contrary effect on the climate such as sulfate aerosols and their durability in the atmosphere. Table 1

[25] For previous section see: Bodansky (2016)
[26] Germanwatch (2017b)

illustrates an estimate of the 20 countries with the highest contributions to global warming, values being given in °C of global temperature change, and a breakdown of their contributions' origins.[27]

Rank	Country	Total	Fossil Fuel CO_2	Land-use CO_2	All CO_2	Non-CO_2 GHG	All GHG	Aerosols
1	United States	0.151	0.143	0.026	0.170	0.044	0.213	−0.063
2	China	0.063	0.042	0.036	0.078	0.049	0.127	−0.065
3	Russia	0.059	0.059	0.014	0.072	0.020	0.092	−0.034
4	Brazil	0.049	0.004	0.032	0.036	0.018	0.054	−0.005
5	India	0.047	0.013	0.025	0.037	0.025	0.062	−0.015
6	Germany	0.033	0.035	−0.000	0.035	0.008	0.042	−0.009
7	United Kingdom	0.032	0.031	0.001	0.033	0.007	0.040	−0.007
8	France	0.016	0.014	−0.000	0.014	0.007	0.021	−0.005
9	Indonesia	0.015	0.003	0.013	0.015	0.006	0.021	−0.006
10	Canada	0.013	0.011	0.007	0.017	0.005	0.023	−0.009
11	Japan	0.013	0.021	0.001	0.022	0.002	0.024	−0.011
12	Mexico	0.010	0.006	0.008	0.014	0.003	0.017	−0.007
13	Thailand	0.009	0.002	0.006	0.008	0.004	0.012	−0.002
14	Columbia	0.009	0.001	0.006	0.007	0.003	0.010	−0.001
15	Argentina	0.009	0.002	0.003	0.005	0.005	0.010	−0.001
16	Poland	0.007	0.010	0.001	0.011	0.003	0.014	−0.007
17	Nigeria	0.007	0.001	0.001	0.002	0.005	0.007	0.000
18	Venezuela	0.007	0.002	0.002	0.004	0.003	0.008	−0.001
19	Australia	0.006	0.005	0.002	0.007	0.006	0.014	−0.007
20	Netherlands	0.006	0.004	0.000	0.004	0.002	0.006	−0.001

Table 1: Top 20 Contributors to Global Temperature Change[28]

Even though China emitted almost twice as much carbon dioxide in 2016 as the USA, the table suggests that historically, the US is the uncontested leader in terms of contributions to global temperature change. This is mainly due to the highest fossil fuel carbon dioxide emissions, contributing to global warming with 0.143°C. Even though the additional carbon emissions from land use are not as high as for China and Brazil, the value is still comparatively high, leading to a contribution of 0.170°C from carbon emissions. Additionally, the US is the second largest emitter of other greenhouse gases and aerosols, the latter offsetting 0.063°C of the greenhouse gas emissions.

2.1.2. Geographic Approach

Still, it can be argued that comparing countries' emissions based on their total emissions might not be a suitable approach as this might disadvantage big countries. Another way to look at a country's contribution to temperature rise is by making the connection to its geographic size. Figure 1: Cartogram of National Climate Contributions, Density-Equalized Map shows a density-

[27] For previous section see: Matthews et al. (2014)
[28] Matthews et al. (2014)

equalized map of the countries' climate change contributions, signifying that the size of each country is proportionate to its contribution. Additionally, the color indicates the factor by which the size of the country has been increased or decreased. For example, the dark red color of Germany shows that the size of the country has been increased by a factor of 22 in order to make its displayed size proportionate to its contributions, whereas regions in light grey have been decreased compared to their actual size. The map implies that, relative to its geographic area, the USA has higher contributions to temperature change than China or Brazil, but less contribution per square kilometer than Germany, the UK or France for example. The indication is that the USA, historically contributing more to climate change than the EU, is more than twice as big as the EU and therefore has a significantly lower contribution per geographic unit. Remarkable is also the fact that Russia's size has been expanded by less than one. This is due to the fact that Russia in terms of its size is by far the biggest country in the world. Therefore, the total emissions are distributed over a relatively vast surface.

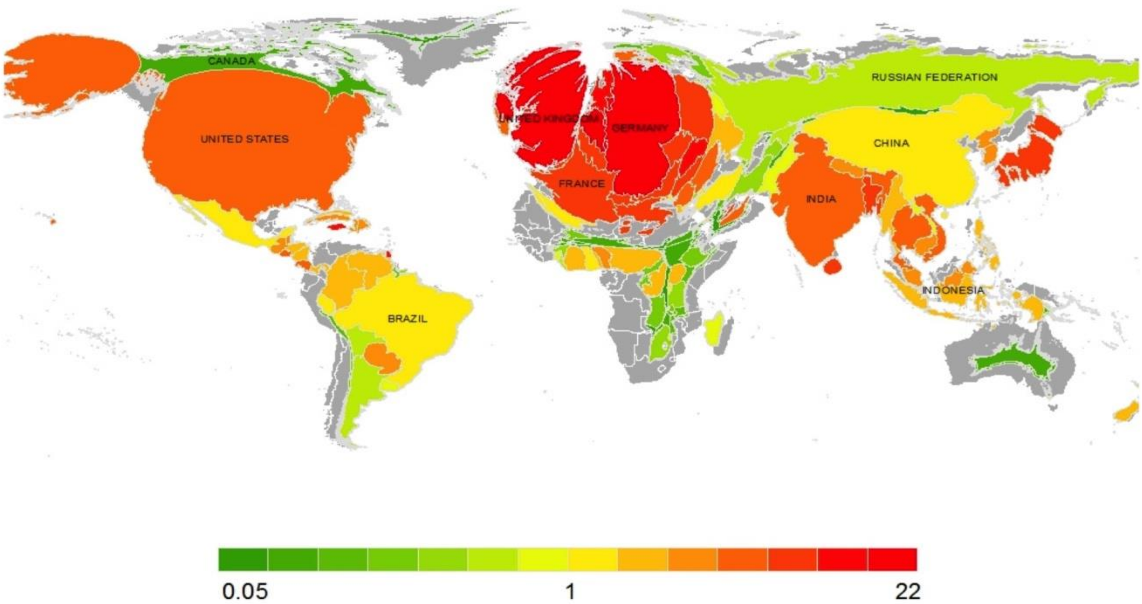


Figure 1: Cartogram of National Climate Contributions, Density-Equalized Map[29]

[29] Matthews et al. (2014)

2.1.3. Per Capita Approach

The approach most often used in comparable studies is the per capita approach. Figure 2 indicates the national contributions to climate change as per capita values. Orange and red fillings indicate per capita contributions above 0.11°C per one billion people, which was the estimated average value in 2005. Countries with lower values are displayed in yellow and green. As can be seen, with this approach, fewer countries in the EU have per capita values significantly above average than with the geographic approach. Still, the EU was amongst the above average contributors. In comparison to the geographic approach, Russia is amongst the top five contributors in terms of per capita contributions, due to the fact that this time, the relatively high contributions are distributed over a moderate number of citizens.

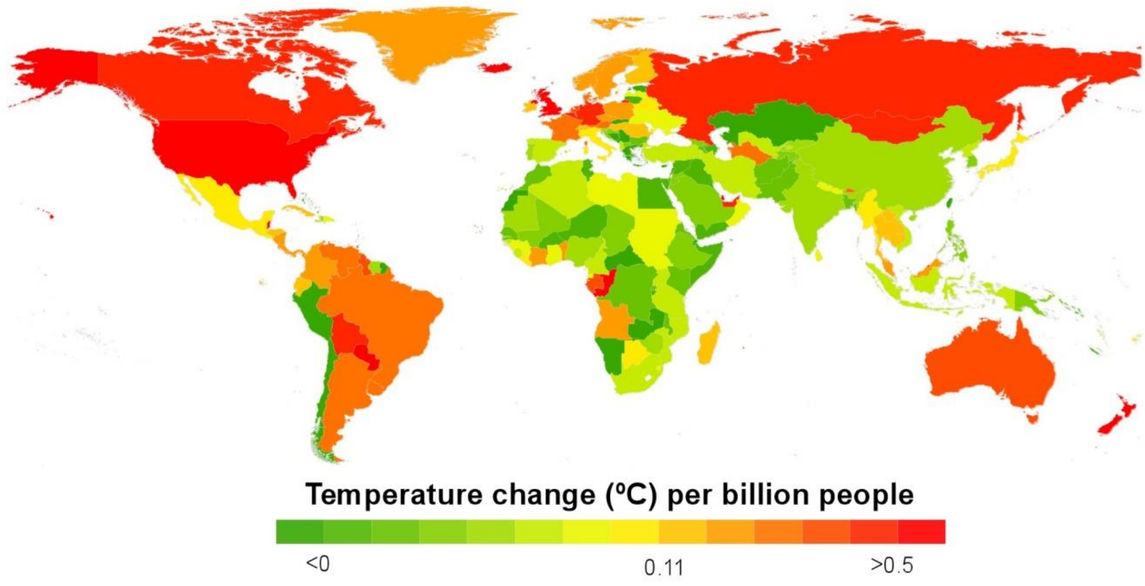


Figure 2: National Per Capita Contributions to Climate Warming[30]

Table 2 compares the top 20 contributors in terms of total contributions to the same countries ranked according to their per capita contributions. Surprisingly, the results are partly differing significantly. While China and India are the second and fifth largest contributors to climate change in total contributions, they are ranked last in terms of its per capita emissions among the 20 countries. Other nations such as the Netherlands or Australia that are at the lower end of the 20 largest contributors are ranked considerably higher with regards to their

[30] Matthews et al. (2014)

per capita contributions. The USA, which is by far the biggest contributor in total, is ranked second in per capita measurement behind the UK, which was formerly placed 7th.

Rank	Total warming °C		Warming per billion people	
1	United States	0.151	United Kingdom	0.54
2	China	0.063	United States	0.51
3	Russia	0.059	Canada	0.41
4	Brazil	0.049	Russia	0.41
5	India	0.047	Germany	0.40
6	Germany	0.033	Netherlands	0.34
7	United Kingdom	0.032	Australia	0.30
8	France	0.016	Brazil	0.26
9	Indonesia	0.015	France	0.26
10	Canada	0.013	Venezuela	0.25
11	Japan	0.013	Argentina	0.23
12	Mexico	0.010	Colombia	0.21
13	Thailand	0.009	Poland	0.19
14	Columbia	0.009	Thailand	0.14
15	Argentina	0.009	Japan	0.10
16	Poland	0.007	Mexico	0.09
17	Nigeria	0.007	Indonesia	0.07
18	Venezuela	0.007	Nigeria	0.05
19	Australia	0.006	China	0.05
20	Netherlands	0.006	India	0.04

Table 2: Total Versus Per Capita Contributions to Temperature Change for the World's Top 20 Total Emitters[31]

It can be concluded that no matter the approach chosen, the US is always amongst the top contributors. For it was the second largest emitter of carbon dioxide in 2016 and historically even the largest contributor to climate change, it seems reasonable to suppose that the USA's actions against climate change could make a huge difference to the success of global actions. Additionally, the fact that it is ranked second for its per capita contributions raises the assumption that there absolutely is potential for the US to make significant contributions to climate protection.

2.2. USA's Performance in Tackling Climate Change

According to the Climate Change Performance Index 2017 by Germanwatch, the US has been downgraded in the overall ranking by eight positions compared to the previous year to position 43 out of 58 assessed countries with

[31] Matthews et al. (2014)

the rating “poor”. It has to be mentioned that the best rating, “very good”, and the first three ranks were not assigned to any country, because the researchers did not consider the achievements of any nation to be sufficient to deserve a top three ranking.

The rating takes into account emissions levels weighted with 30%, the development of emissions, also with 30%, the countries’ climate policies with 20% as well as renewable energies and efficiency with 10%, respectively. The nation has lost ranks in almost all categories, although per capita emissions have been falling since 2007, except for one year.
With regards to total greenhouse gas emissions levels, the USA was rated as very poor as could be expected. Other countries with this rating include Canada, Russia, Australia and Korea. Experts point out that a crucial factor hindering the USA’s greenhouse gas emissions from decreasing are the currently rising methane emissions from shale gas extraction, which replaces the extraction of coal gas. The advice is to limit these in the future. Nevertheless, the US earned a moderate rating for its development of emissions and therewith surpasses big parts of South America and Asia, as well as some European countries like Germany, Norway and Poland.
Also regarding renewable energies, the country achieved a moderate rating, so did China and India amongst others, while for example Russia, Mexico, Australia and Canada were rated as poor to very poor.
The efficiency assessment, which takes into account the carbon intensity of a country’s primary energy supply and the country’s economy’s energy intensity, rated the USA’s efficiency as poor. The same applies to Brazil, Germany and India for example. Other countries, including Canada, Australia and Russia were rated even worse, while Argentina, Indonesia, France and most other European countries were rated moderate or better.
Concerning the climate policy variable, it is stated that on the one hand, under Obama’s administration, the USA held a central role in international climate change negotiations, for instance by pushing agreements forward and involving other important countries like China and India. On the other hand, the country’s climate policy is criticized for the insufficient support in the loss and damage question during the COP21 negotiations. Furthermore, the study highlights that

the USA's next years' climate policy in severely endangered due to Trump's election in November 2016. Therefore, the nation was rated moderate, so were Brazil, Canada and Russia amongst others. A few countries were rated good, including India, Sweden and Germany and last year's leader, China, was replaced by Morocco. This part of the assessment allows poorly rated countries to improve on their valuation as soon as their intention to make progress is recognizable. This applies to the Netherlands, Switzerland, Portugal and especially South Africa, that has improved by 16 positions and achieved a good rating as well.[32]

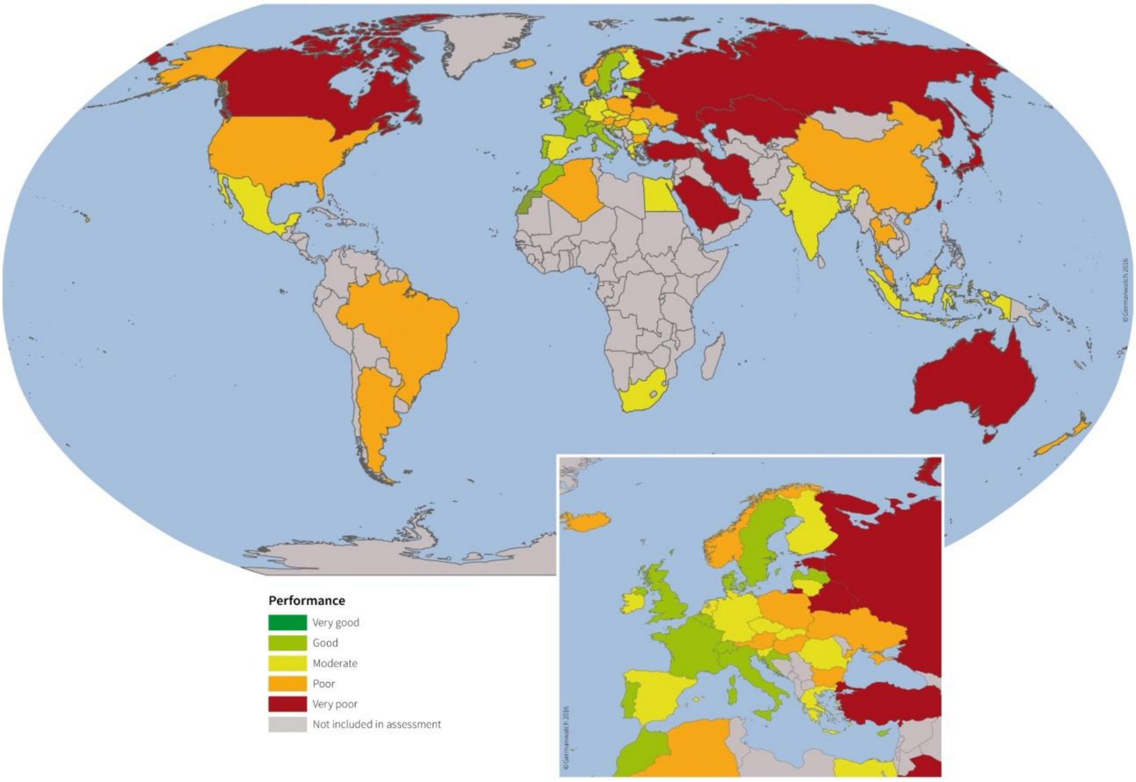


Figure 3: CCPI World Map 2017[33]

Figure 3, a world map of the overall results of the CCPI 2017, allows a comparison of the USA with other countries. It has to be mentioned that in the ranking, the US were ranked lower than most of the other orange countries of which the overall performance was rated as "poor", such as Brazil, Argentina and Poland. Even though the USA were still ranked higher than Canada, Russia, Australia, Japan, China and some other countries, all EU member

[32] Germanwatch (2017a)
[33] Germanwatch (2017a)

states were ranked higher except for Estonia. Compared to last year's ranking, Portugal and Croatia were the only countries upgrading from moderate to good performance. The good performance group, having been headed by Denmark during the last four years, is now led by France, Sweden and the UK. Analyzing the data given by regions, Europe is leading, followed by South America, Asia, North America and Australia. Most parts of Africa are not included in the assessment. Striking is the fact that amongst the ten largest carbon dioxide emitters in terms of total emissions in 2016, the USA were ranked third highest behind India and Germany. This is because out of the seven remaining largest carbon emitters in the world all, except for China, were rated as very poor. Vice versa, this also implies that out of the 13 countries of which the performance was rated as very poor, almost half belong to the ten largest carbon emitters.[34]

2.3. USA in Climate Change Negotiations

2.3.1. Population's Standpoint

The USA's position in climate change negotiations was probably one of the most unsteady ones. This might be due to the fact that also the population itself is deeply disrupted concerning the climate question. As Figure 4 shows, more than three fourths of the population agree that the government should address climate change and therefore support the USA's participation in the Paris Agreement. However, only 36% think that climate change is a serious problem the world has to face. This lies dramatically below the global survey average of 52%. With regards to the participants own willingness to contribute to tackling climate change, almost half stated they would not even be willing to participate with one dollar per month.

[34] Germanwatch (2017a)

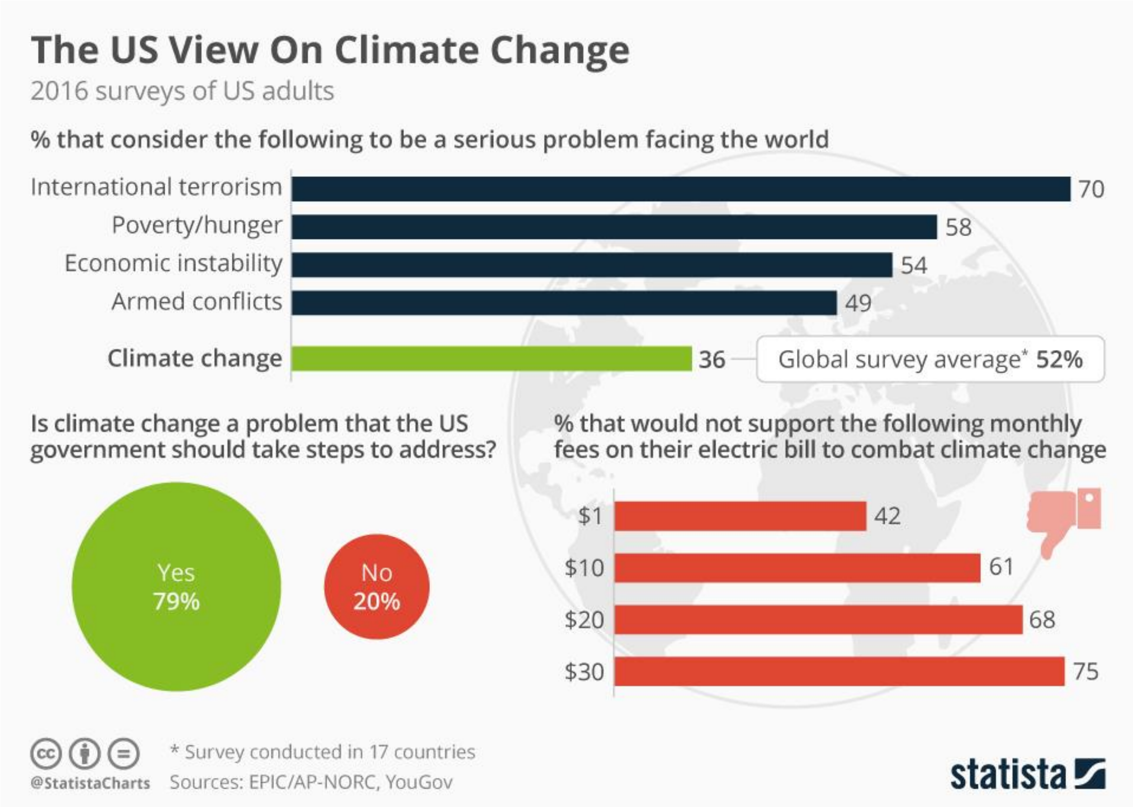


Figure 4: The US View on Climate Change[35]

Another survey from November 2015, conducted in 17 countries, suggests that in the US, only 9% of the population consider climate change to be the most serious problem the world has to face at this point in time. The only country that scored even lower was Saudi Arabia with 5%. The absolute leader was Hong Kong with exactly one fourth of the population viewing climate change as the most serious issue, followed by Sweden, Denmark, Singapore and China. Most of the countries in the midrange were settled around 12% to 13%. This group consists of Norway, Finland, Australia, Germany, Thailand and the United Arab Emirates. Finally, the four countries coming closest to the USA and Saudi Arabia were the UK, France, Indonesia and Malaysia with 10% to 11%.[36] Additionally, another study investigated the share of US citizens that agreed to the statement that scientists understood that climate change was occurring. It was found out that among the moderate or liberal Republicans, only 24% agreed to the statement. For the conservative Republicans the share was even lower with 18%, being well below the US average of 33%. The moderate or

[35] Statista (2017a)
[36] YouGov (2015)

conservative Democrats on the other hand agreed to 31%, which was still topped by far by the liberal Democrats, agreeing to 68% to the statement.[37] The population's attitude towards climate change is inevitably reflected in the governments voted.

2.3.2. Presidents' Standpoints

Even though some presidential records from the Nixon Presidential Library and Museum indicate that already the Nixon administration had several debates about the subject of climate change in 1969[38], Obama is considered to be the first president of the US who has ever actively taken a stand against climate change[39], after the Kyoto Protocol had never been ratified by the US. Obama's Climate Action Plan was based upon three pillars: cutting the nation's carbon pollution, preparing the country for the impacts of climate change and taking the lead in international efforts to tackle global climate change. The first pillar mainly focused on the topics of clean energy, transportation, energy waste, other greenhouse gas emissions and exemplary behavior at the federal level. The second pillar addressed community and infrastructure improvements, the protection of natural resources and therewith the economy and finally making use of scientific tools and insights in order to manage the impacts of climate change. The last pillar is firstly concerned with the collaboration of the US with other nations in various ways that can have an influence on climate change and secondly with the positioning of the US as a leading force in international climate change negotiations.[40]

However, since President Trump's inauguration in January 2017, the US has adopted a new course of action. Apart from nullifying climate protecting regulations, rules and policies[41] such as Obama's Clean Power Plan[42], the new administration also stated to be envisioning withdrawing from the Paris Agreement and potentially renegotiating the agreement[43]. This would make the US join Nicaragua and Syria as the only non-signatory countries in the world.

[37] Pew Research Center (2016)
[38] NBC News (2010)
[39] The Guardian (2015b)
[40] For previous section see: Executive Office of the President (2013)
[41] CNN (2017b)
[42] The Ney York Times (2017)
[43] Trump (2017)

Nevertheless, Germany's, France's and Italy's leader jointly stated that a renegotiation was unthinkable.[44]

2.3.3. States' and Cities' Standpoints

In his statement, Trump also said the US would *"continue to be the cleanest and most environmentally friendly country on Earth"*[45]. Although the term *continue* can be confusing given the results of many climate-related studies, the president emphasized the US would manage to be the worldwide leader concerning environment issues, even without the Paris Agreement and Obama's regulations. This point of view, however, is not shared by some of the USA's states and cities, which have for this reason founded the U.S. Climate Alliance. Figure 5 shows the twelve states being member to the Alliance in green, the ten states that committed to still follow the guidelines of the Paris Agreement in blue and 274 cities having signed the Mayors National Climate Action Agenda in purple.

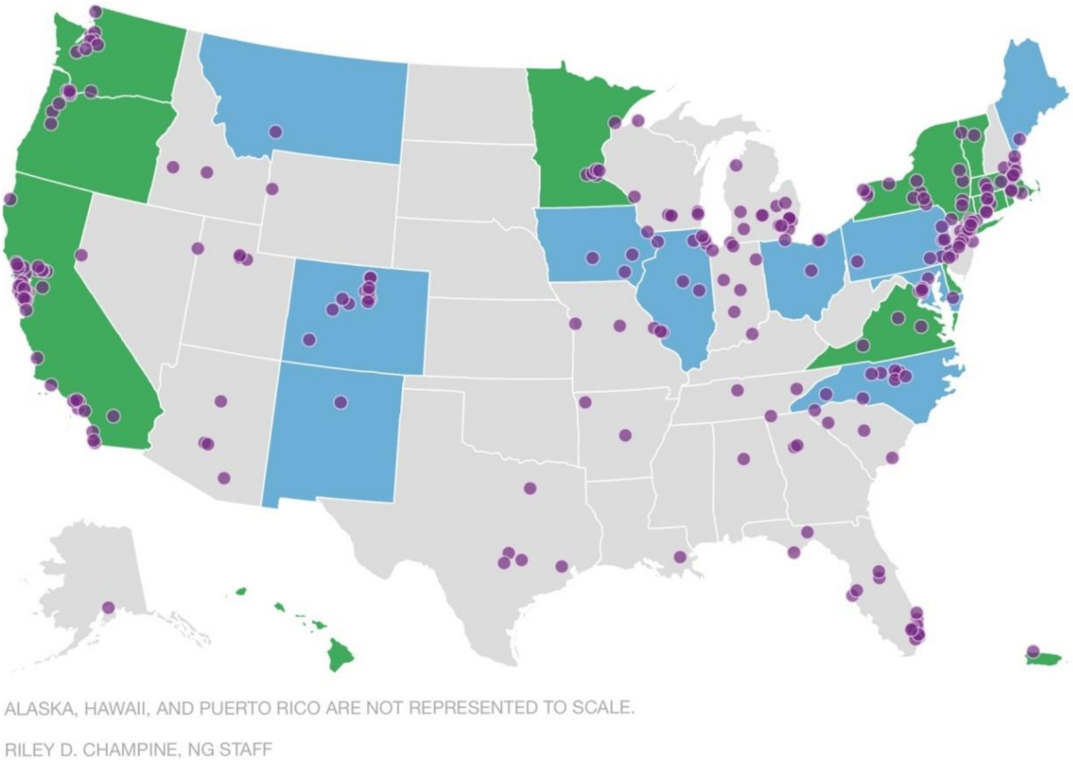


Figure 5: States and Cities in the US Committing to Climate Protection[46]

[44] For previous section see: Statista (2017b)
[45] Trump (2017)
[46] National Geographic (2017)

Additionally, Puerto Rico is part of the U.S. Climate Alliance, the District of Columbia pledged to adhere to the Paris Agreement and more than 900 businesses, 183 universities and colleges and 125 cities declared their participation in the initiative "We Are Still In" by New York's former mayor Bloomberg. The latter also pledged to donate an amount of $15 million to the UFCCC to compensate gaps in the funding that might occur due to Trump's climate policy.[47] To what extent actions undertaken by parts of the US will play a role in international climate negotiations, however, will have to be monitored in the future.

3. Introduction to Game Theory

3.1. General Introduction

According to the Oxford Dictionary of English, game theory is *"the branch of mathematics concerned with the analysis of strategies for dealing with competitive situations where the outcome of a participant's choice of action depends critically on the actions of choice of other participants."*[48] Since having become a formal topic of studies in the 1950s, it has been used in various contexts of economics as well as in business, war, evolutionary biology, ecology, political science and others. The mathematicians John von Neumann and John Nash along with the economist Oscar Morgenstern are considered to be the forerunners of the still relatively new and growing science.[49]

3.2. Players, Games and Payoffs[50]

In game theory, situations in which participants can take a strategic decision are called a ***game***. Even though the participants may not literally be playing but for example negotiating or fighting, they are called ***players*** in game theoretic terms. The different ***payoffs*** are represented by numbers that indicate how desirable any possible outcome of the given situation is.

[47] National Geographic (2017)
[48] Oxford Dictionary of English: https://en.oxforddictionaries.com/definition/game_theory
[49] For previous section see: Schwalbe, Walker (2001), pp. 123-137
[50] For a detailed introduction see for example: Von Stengel and Turocy (2001) or Matsumoto and Szidarovszky (2016)

3.3. Strategies

Every possible action that a player can take is called a ***strategy***. If a strategy is always the better option for a player, no matter what the other players do, it is called a ***dominant*** or ***dominating strategy***. On the other hand, if a strategy is constantly dominated by another strategy, game theorists talk about a ***strictly dominated strategy***. A strictly dominated strategy is never played by rational player.
A strategy that is always at least as good as the other possible strategies, regardless of what the other players do, is called a ***weakly dominant*** or ***weakly dominating strategy***. Opposed to this is the ***weakly dominated strategy***.

Strategies can be ***strictly efficient***, which indicates that the whole population is better off if all players opt for one identical strategy.

Instead of playing a ***pure strategy***, players can also choose a ***mixed strategy***, which means that they randomly, but with a certain probability, opt for one of their strategies.

3.4. Nash Equilibrium and the Chicken Game

The ***Nash Equilibrium*** indicates the set of strategies that maximizes the payoff of each player depending on the other players' strategies. This means that no player can maximize his payoff by unilaterally changing his strategy.
One of the most common games with a Nash Equilibrium is the ***Chicken Game***.
In this game, two drivers want to prove their courage by driving towards each other. However, one of them must swerve or they will both die in the car crash.
This means that there are four possible outcomes:

- Both of them drive straight. In this case, they will die and their payoff is -5. This is the worst that can happen to both of them.
- Driver 1 swerves while driver 2 drives straight. In this situation, driver 2 wins the game and the benefit of winning is 3 while driver 1 loses the game and will be called a "chicken". He gets a payoff of 0 for he has lost the game but at least he has not died.
- Driver 2 swerves while driver 1 drives straight. In this situation, driver 1 wins the game and the benefit of winning is 3 while driver 2 loses the

game and will be called a “chicken”. He gets a payoff of 0 for he has lost the game but at least he has not died.

- Both of them swerve. In this case, they both get a payoff of 1 because they are both alive and none of them has lost the game against the other player.

To illustrate this situation, the following matrix can be used:

		Driver 2	
		Swerve	**Drive straight**
Driver 1	**Swerve**	**1, 1**	**0, 3**
	Drive straight	**3, 0**	**-5, -5**

Matrix 1: Chicken Game

As we can see, the chicken game is an ***anti-coordination game***, which means that in any case, the best strategy for driver 1 is the opposite of driver 2’s strategy and vice versa. This means that if driver 2 swerves, it is best for driver 1 to drive straight in order to win. On the other hand, given that driver 2 drives straight, the best strategy for driver 1 is to swerve to avoid a collision. This indicates the two Nash equilibria, i.e. the two sets of strategies that maximize the drivers’ payoffs given the strategy of the other driver, in the chicken game:

		Driver 2	
		Swerve	**Drive straight**
Driver 1	**Swerve**	**1, 1**	**0, 3**
	Drive straight	**3, 0**	**-5, -5**

Matrix 2: NE Chicken Game

It can be argued that for example, driver 1 considers swerving the only reasonable strategy, as the cost of dying is significantly higher than the cost of losing the game. However, he might think that driver 2 thinks the same and therefore driver 1 drives straight because he expects driver 2 to swerve. But then he might think that driver 2 thinks that he thinks that it is the most reasonable to swerve and therefore expects driver 2 to drive straight and will consequently prefer to swerve. This can be continued endlessly and finally, one cannot predict which driver will be the one swerving. In many cases, these games are solved through commitment. If one driver acts like being crazy and not caring about life before the race, this might convince the other player to swerve, whereas behaving unconfident and afraid might lead to the opposite.

Dynamic or continuous games can be ***subgame perfect***, meaning that every subgame, i.e. every round played, can be solved with a Nash equilibrium using a certain strategy profile.

3.5. Criticisms of Game Theory

"As far as I'm concerned, the opinion of […] people [such as Rabbi Meizel, the communist Sala Marcel, my widowed Aunt Hannah, and the intellectual Yaacovson] is just as authoritative for making social and economic decisions as the opinion of an expert using a model"[51], states Ariel Rubinstein, currently one of the leading heads and most renowned game theorists in the world. In his book *Economic Fables* he stresses that game theory, as well as any other model, tries to abstract complicated situations and thoughts by fitting them into formalized models. He compares game theory to a collection of fables that can indeed help to gain new insights and look at situations from other perspectives but is unable to give concrete advice on how to solve a problem better than an amateur.

Two other criticisms of game theory are that first of all, players are assumed to be rational, which has been proven to not always be the case. Secondly, game theoretic models have to be fed with high quality data in order to produce high quality data. This means that apart from an understanding of game theory, also subject specific knowledge is indispensable in order to correctly assess the situation, the factors involved and the influence these factors have.

It can be concluded that game theoretic models can be helpful for gaining insights and an understanding of situations and behavior, but should not be seen as an infallible source of information and guidance.

> *Chapter Conclusion: First of all, it can be concluded that despite the continuous diplomatic efforts made to tackle the problem of climate change during more than 25 years, the results still*

[51] Rubinstein (2012)

appear to be insufficient. Secondly, the US has proven to be a factor fundamentally influencing both, climate change and the related negotiations. Thirdly, game theory can be used as a tool to gain a deeper understanding of a situation and develop new insights in a topic.

Understanding International Climate Change Negotiations in the Context of Game Theory

Chapter Outlook: This chapter presents several approaches to understanding climate change negotiations using game theoretic tools. At first, it will be investigated how climate change negotiations can be modelled as a game. In a second step, it will be illustrated through which factors the game could be shifted from a prisoner's dilemma to a potentially more favorable coordination game. Some mechanisms to overcome one factor, the free rider effect, will be given thereafter. Finally, it will be explained under which circumstances a population will actually choose the efficient equilibrium in a coordination game, which ultimately makes this game more favorable than a prisoner's dilemma and which characteristics make a climate agreement successful.

4. The Climate Game

4.1. Using Game Theory to Predict Climate Change Negotiations: The Predictioneer's Game

That game theory can be a useful tool to foresee how political and economic events could approximately transpire and even predict the outcomes of negotiations has been repeatedly demonstrated by the game theorist Bruce Bueno de Mesquita. With an accuracy of 90%, his forecasts are being bought by international corporations, governments as well as the CIA, which stated that Bueno de Mesquita's models were twice as often correct as its traditional analyses. Amongst others, he had successfully predicted the outcomes of

2009's climate change negotiations in Copenhagen in his book *The Predictioneer's Game*.[52]

4.1.1. Modeling Climate Change Negotiations[53]

In order to collect the needed data to feed his game theoretic models, he first assesses who the main players are and what view they take concerning the relevant topic. In case of climate change negotiations, Bueno de Mesquita took those governments and interest groups, more precisely NGOs and multinational corporations, into account that were most affected, also bearing in mind that there was a fraction favoring the regulation of carbon dioxide emissions and one opposing for both, multinational corporations (CorpFor and CorpAgainst) and the USA (USPro and USAnti).

In a second step, the game theorist estimates whether the different stakeholders have a high potential influence on the negotiations or a rather low one, what their position on the topic is, how strong the salience is that the respective parties attach to the issue and how much they are committed to finding a consensus.

For example, in his calculations for climate change negotiations (see Table 3), the EU scored an 87 in terms of influence whereas Japan had a medium value of 15 and NGOs had a low influence in the negotiations of 1. The position on the topic was evaluated on a scale from 1 to 100, where 100 represents the absolute wish for emission controls, a value of 1 indicates a position that is absolutely against emission controls and 50 is neutral. While NGOs, the EU and CorpFor achieved high values, Japan was slightly against it and CorpAgainst, China, India and Brazil were on the lower end of the scale. The salience of each stakeholder can also range from 1 to 100, meaning that Australia with a score of 50 did not particularly emphasize the question of mandatory emission controls, compared to the EU, NGOs, China, India and Brazil that did strongly stress it.

The desire for an agreement, no matter whether in favor of the own position or

[52] For previous section see: Wirtschaftswoche (2010), pp. 70-72
[53] For entire section see: Bueno de Mesquita (2009)

not, was estimated at values ranging from 60 in the case of Japan and Russia, representing an over average desire for agreement, to 10 for CorpAgainst.

Stakeholder	*Influence*	*Mandatory Emission Controls*	*Salience*	*Desire for Agreement*
Australia	6	65	50	50
Canada	9	60	50	50
EU	87	95	90	35
Japan	15	45	60	60
Russia	6	40	50	60
USPro	65	70	70	40
USAnti	35	30	50	30
CorpFor	3	95	50	50
CorpAgainst	3	1	75	10
NGOs	1	99	99	20
China	15	5	90	30
India	9	5	90	30
Brazil	4	3	90	40

Table 3: Underlying Data for Bueno de Mesquita's Predictions[54]

The information needed to evaluate the scores was mainly derived from interviews with experts and negotiators. Feeding his models with these values and adding a 95% confidence interval for all kinds of scenarios, Bueno de Mesquita came to the conclusion that Copenhagen would default in producing a successor treaty to Kyoto and instead leave the world with a weak deal that would not have a long-term impact.

4.1.2. Criticism

Bueno de Mesquita’s models are, despite their relatively high hit rate, often criticized for not taking into account a country’s or party’s history and culture, as these might also be factors influencing the actions and reactions of the negotiators. On the other hand, this can also be seen as strength of the model for trends and behavior from the past are not projected on the future.

A second criticism is that, apart from the assignment of values to a few variables, the models are entirely computer based instead of relying on a

[54] Bueno de Mesquita (2009), p.217

human's good judgement at last instance. Bueno de Mesquita himself states that he had shown his counterparts proofs, publications and predictions that had been fulfilled but that anyway he had gotten the reaction that this might be the case but that their problems were not computer solvable[55]. Nevertheless, many supporters of his models consider this to be a huge advantage as it can be ensured that the results are not influenced by the personal wishes and beliefs of the person conducting the forecasts.

Bueno de Mesquita himself sees the greatest threats of failure for his models in irrational behavior, unconsidered maximization strategies and wrong data and admits sometimes being surprised by the accuracy of the results despite all these things. [56]

4.1.3. Reasons for Weak Outcomes in Climate Change Negotiations

According to *The Predictioneer's Game*, it is not surprising that international climate change negotiations produce weak results; the author even takes the view that they will not help to stop global warming but could possibly even harm, as they create the feeling that something is being done, even though this is not enough. He argues that climate agreements are not successful in reducing carbon emissions because they either do not demand much effort and change from the participants or they have no mechanisms to punish the non-fulfillment of pledges as they have to be built upon the lowest common denominator in order to achieve high participation. Bueno de Mesquita uses the example of the Kyoto Protocol, stressing that first of all, out of the 175 nations that have ratified the accord, 137, including the emerging economies of Brazil, India and China, were only obliged to report on their greenhouse gas emissions without signing a pledge, which made compliance no problem for them. Secondly, he mentions that there was no mechanism to punish those nations which did not comply with their pledges such as Japan and the UK, which facilitated signing the protocol without honestly planning to pursue the goals. [57]

[55] Cf. Wirtschaftswoche (2010), pp. 70-72
[56] For previous sections see: Wirtschaftswoche (2010), pp. 70-72
[57] For previous sections see: Bueno de Mesquita (2009)

Finally, the game theorist explains his view that in negotiations over a common resource, nations, if they are willing to make sacrifices at all, tend to make promises that they are unable to keep afterwards, which he compares to "cheating" [58] in a game. He concludes that the problems in climate change negotiations can be traced back to the tragedy of the commons, which will be explained in the next chapter.

4.2. Tragedy of the commons

The tragedy of the commons is a theory in economics that describes how the individual interest to exploit a resource in order to optimize individual profits can lead to the exhaustion of the latter, which means that it is finally unavailable for the entire group.

This concept became widely known since the paper "The tragedy of the commons" by Garrett Harding, which dealt with the increasing concern of overpopulation, was published in 1968. The example he used was common grazing land that could provide a certain amount of animals with an adequate amount of food. However, if the number of grazing animals was increased, the land became unable to reproduce itself and none of the animals could find any more food.

A real world example of the tragedy of the commons is the cod fish industry on the coast of Newfoundland. For centuries, there had been enough cod fish for all the fishermen in the area and not more cod fish had been caught than the fish population was able to reproduce. Yet, as soon as fisherman became able to catch higher amounts of cod fish than before, due to improvements in fishing technologies in the 1960s, they started fishing more and more in order to maximize their individual profits. The result was that the fish population was unable to reproduce itself and the whole industry collapsed in the 1990s.[59]

The same principle can be applied to climate change, considering climate and therefore the world as we know it as a common resource with limited ability to recover, shared among all people and countries and even shared among

[58] Cf. Bueno de Mesquita (2009)
[59] For previous sections see: Investopedia: www.investopedia.com/terms/t/tragedy-of-the-commons.asp

today's and future generations. If climate is damaged today for the individual interests of single countries, to an extent that cannot be offset by the planet, then future generations will have to bear the consequences that a collapsing climate system brings and in the end the situation will be worse for all countries than if the resource had only been used to the extent that it can support.

4.3. The Climate Game as a Prisoner's Dilemma

What is known as the tragedy of the commons in economics and other fields of science, can be explained using the model of the prisoner's dilemma in game theory.

4.3.1. The Prisoner's Dilemma Game

Originally, the prisoner's dilemma describes a situation in which two criminals are believed to have committed a crime that would bring them to prison for ten years. They are both arrested separately without any possibility to communicate. As the policemen do not have enough evidence to sentence the two criminals for the entire ten years, they propose a deal to each one of them. If they both confess, they will go to prison for ten years. If criminal 1 confesses while the other one denies, criminal 1 will be set free while criminal 2 will be sentenced for 15 years and vice versa. If both of them stay silent, the policemen can only arrest them for five years due to lacking evidence. This leads us to the following matrix in years:

		Criminal 2	
		Confess	**Deny**
Criminal 1	**Confess**	**10, 10**	**0, 15**
	Deny	**15, 0**	**5, 5**

Matrix 3: Prisoner's Dilemma

Converting the years into payoffs, the matrix could look like this:

		Criminal 2	
		Confess	Deny
Criminal 1	Confess	-2, -2	0, -3
	Deny	-3, 0	-1, -1

Matrix 4: NE Prisoner's Dilemma

If criminal 2 confesses, the best response for criminal 1 is to confess as well. If criminal 2 denies, it is still the best strategy for criminal 1 to confess and vice versa. Obviously, confessing is a dominant strategy for both of them, because there is no incentive to deviate in order to maximize the payoffs. Therefore, the Nash equilibrium is (confess, confess). However, the Nash equilibrium is not the optimal outcome: For both of them, the payoff could have been higher in the case (deny, deny). The prisoner's dilemma shows that pursuing individual interests does not necessarily lead to the optimal outcome for all players.

4.3.2. The Prisoner's Dilemma in Climate Change Negotiations

Climate change negotiations can also be modelled as a prisoner's dilemma. Highly simplified, it can be assumed that a single country can either choose to continue exploiting the climate or to act against climate change. However, this has a certain cost. This could result in the following four scenarios:

- If the single country along with all the other countries, i.e. the rest of the world, decides to act against climate change, they all bear the cost while benefitting from a reduced risk of climate change.
- If the single country chooses to act against climate change but the others choose to exploit, the single country bears the cost alone while the other countries can create benefits and a competitive advantage from the exploitation. Additionally, the single country's sole efforts to reduce the risk from climate change most probably are not sufficient to make a difference.

- In the case that all countries decide to exploit the climate, they can all create some benefits right now but have a high risk of climate change with severe consequences in the future.
- Finally, if the rest of the world chooses to act against climate change and bears the associated costs and the single country continues exploiting, it can still benefit from a reduced risk of climate change but has no cost for the required investments while creating a competitive advantage.

As a matrix, the game looks as follows:

		Rest of the World: Act	Rest of the World: Exploit
Single Country	Act	cost but reduced risk, cost but reduced risk	cost and high risk, benefit and high risk
Single Country	Exploit	benefit and reduced risk, cost but reduced risk	benefit and high risk, benefit and high risk

Matrix 5: The Climate Game, Prisoner's Dilemma

Depending on whether the risk of climate change is considered to outweigh the cost of acting against it or not, payoffs can be distributed differently. This can vary from country to country. For example, while one country might suffer strongly from climate change, e.g. small island states, another country might in the beginning even benefit from global warming due to better access to oil as a result of melting polar ice caps or other developments. Assuming a stage of climate change in which countries attribute a cost of -3 to the potential risk of global warming and a cost of -1 to the immediate costs for acting against it, whereas the benefit from exploiting might be represented by a payoff of +1, the matrix for the single country looks as follows:

		Rest of the World: Act	Rest of the World: Exploit
Single Country	Act	-1	-4
Single Country	Exploit	1	-2

Matrix 6: The Climate Game, Payoffs Prisoner's Dilemma[60]

[60] For a matrix breakdown see Annex: Matrix 1 (Breakdown: The Climate Game, Payoffs Prisoner's Dilemma)

Given that the rest of the world decides to exploit, the best strategy for the single country is to also exploit in order to maximize its payoff. However, given that the rest of the world acts against climate change, it still is the best choice for the single country to exploit because it can free ride, i.e. it can still benefit from a reduced risk of climate change while benefitting from the exploitation. This means that exploiting is the dominant strategy for the single country and the best outcome for it would be if the rest of the world acted but the country itself continued to exploit. If this applies to every country, the prisoner's dilemma is inevitable, because there is no incentive for a single country to unilaterally switch its strategy. Every country will choose to exploit at a payoff of -2, even though the world could have done better and every country could have increased its payoff with the option (act, act) and with a payoff of -1. Assuming a continuous risk reduction from acting against climate change, the following graph illustrates a single country's payoff function given the number of other countries acting against global warming:

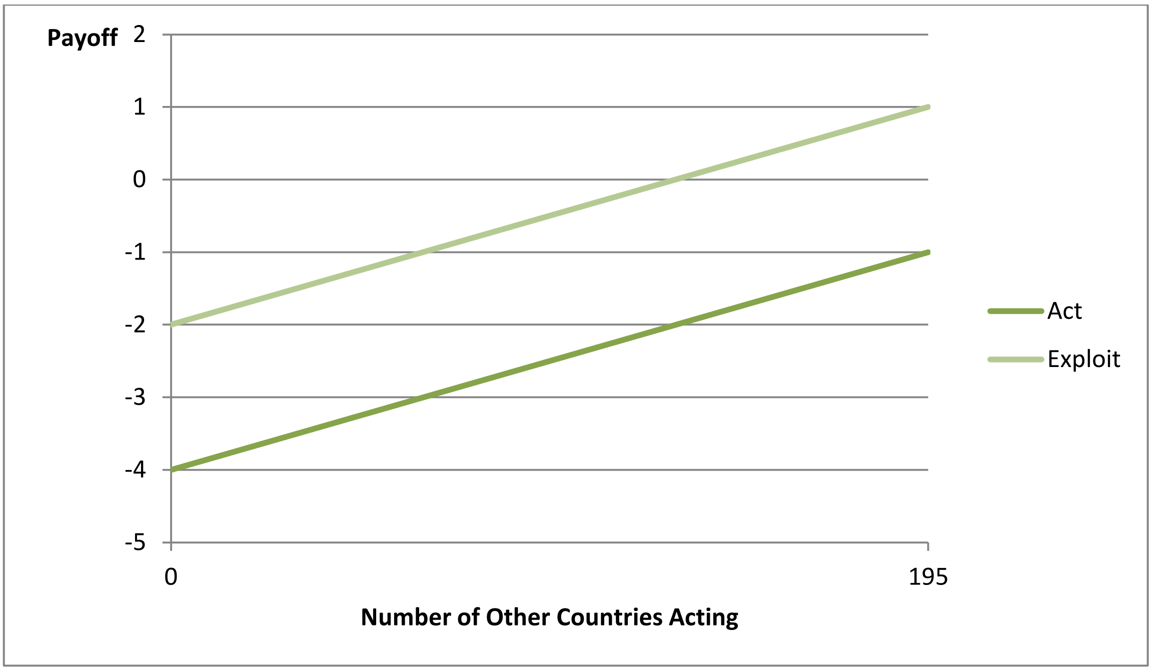


Figure 6: Payoff Function Prisoner's Dilemma[61]

It is obvious that independent of the number of other countries acting, the payoff of a single country is strictly higher when exploiting.

[61] Own illustration

The game theorist Barrett states that what is important to know, is that international agreements are highly unlikely to succeed when they are based on voluntary cooperation, which is required in order to solve the prisoner's dilemma, but quite likely to succeed when being based on coordination instead[62]. How coordination games such as the stag hunt game work and how climate negotiations can be modelled using this type of game will be discussed in the following chapter.

4.4. The Climate Game as a Coordination Game

The main difference between a stag hunt game, i.e. a coordination game, and a prisoner's dilemma is that in the latter, the players are always better off not cooperating, i.e. exploiting, even if they know that the other party will cooperate, In the stag hunt game, this is not the case: both parties are better off coordinating their strategies.

4.4.1. The Stag Hunt Game

Originally, the stag hunt game models a situation in which two huntsmen go out hunting individually, knowing that the other one is out in the forest as well. They can choose to either hunt a hare, which is not worth very much but can be caught by a single person, or to hunt a stag, which is worth much more but is impossible to be caught by one person alone. This means that the chances for catching a hare always stay the same, independent of what the other huntsman does. However, the chances for hunting a stag drastically increase if both huntsmen opt for hunting the stag. As shown in the following matrix, there are two pure strategy Nash equilibria:

		Huntsman 2	
		Stag	**Hare**
Huntsman 1	**Stag**	**5, 5**	**0, 1**
	Hare	**1, 0**	**1, 1**

Matrix 7: Stag Hunt

If huntsman 2 decides to hunt a hare, huntsman 1 is better off also hunting a hare. Yet, if huntsman 2 chooses to hunt a stag, there is no incentive for hunting

[62] Barrett (2013)

a hare instead of a stag. Despite the two equilibria, only the Nash equilibrium (stag, stag) is strictly efficient, meaning that both huntsmen would be better off opting bilaterally for this option.

4.4.2. The Stag Hunt Game in Climate Change Negotiations

Climate negotiations can be modelled accordingly, assuming that the frequently cited 2°C limit of global warming was slightly beyond an absolute threshold which, if crossed, led to a total climate catastrophe including enormously rising sea levels, millions of people from coast areas becoming climate refugees, severe droughts, bush fires and floods. This changes the payoff structure completely. While the benefit from exploiting remains at 1 and the cost of acting against global warming might even triple to -3, the former *risk* of climate change will then change to being a *fact* with a cost of -6. To simplify the model, it will be supposed that every country has either the option to limit its greenhouse gas emissions at least to the amount that equals 2°C relative to the country's stake or to continue exploiting. This implies that if only one country defects, the tipping point will be crossed at a cost of -6. This results in the following matrix:

		Rest of the World	
		Act	**Exploit**
Single Country	**Act**	**-3, -3**	**-9, -5**
	Exploit	**-5, -9**	**-5, -5**

Matrix 8: The Climate Game, Stag Hunt[63]

Assuming that the cost from climate change stays continually the same until the threshold of 2°C is reached, i.e. every country is participating, the following graphs show a single country's payoff function given the number of other countries acting against global warming:

[63] For a matrix breakdown see Annex: Matrix 2 (Breakdown: The Climate Game, Stag Hunt)

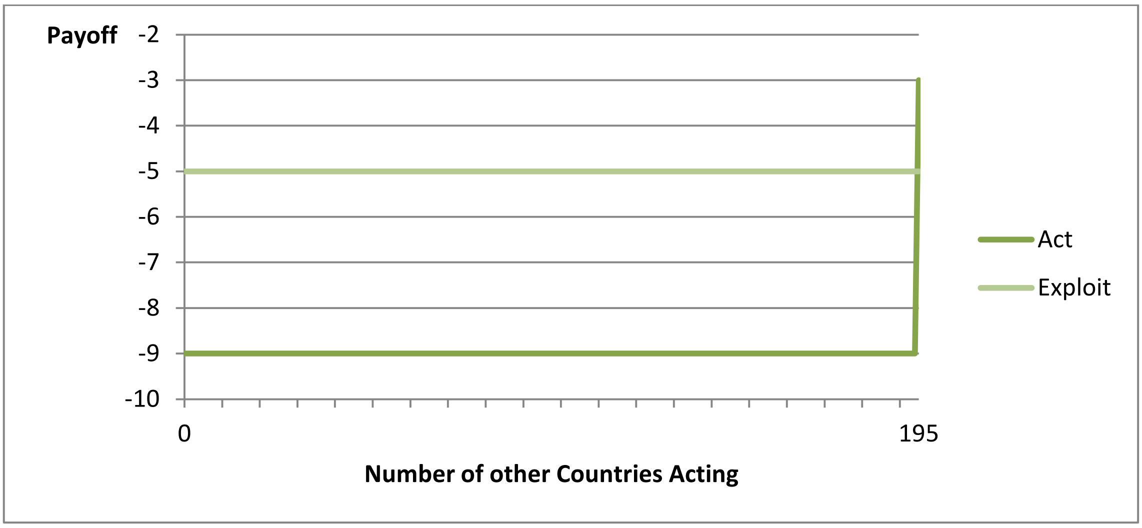


Figure 7: Payoff Function, Stag Hunt 1[64]

As can be seen, in the interval [0;194], the single country's payoff from exploiting is constantly higher than from acting, equal to the prisoner's dilemma's situation. However, the second graph allows a closer insight in what is happening when instead of 194 all other countries, i.e. 195, choose to act against global warming:

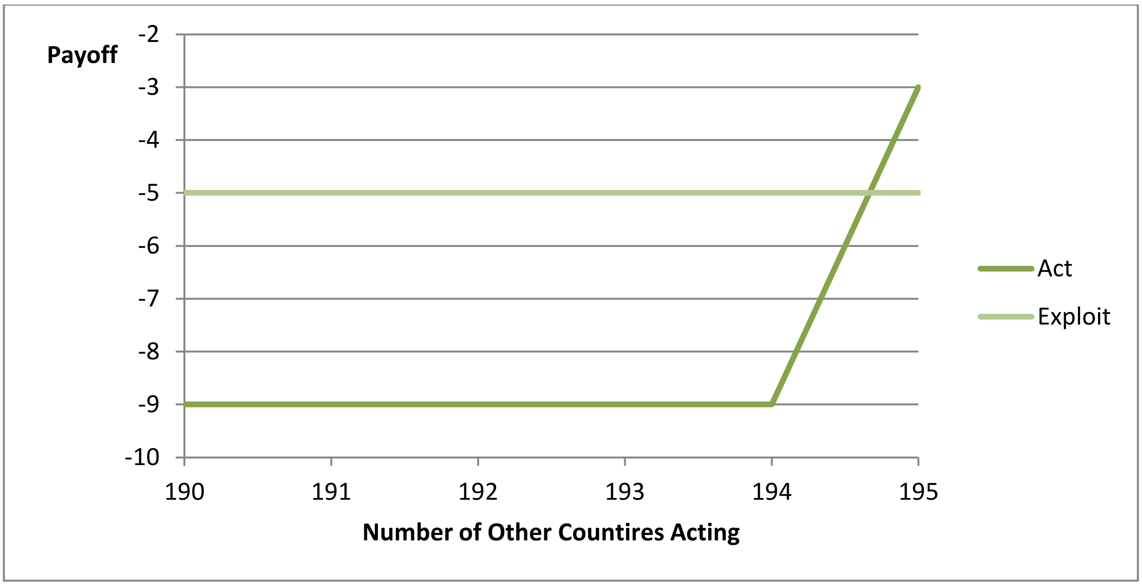


Figure 8: Payoff Function Stag Hunt 2[65]

64 Own illustration
65 Own illustration

At the point at which all other countries have decided to meet the country specific goal of limiting their emissions to the equivalent of 2°C, the single country's payoff from acting exceeds the one from exploiting by two. This is of course an enormous incentive for the country to act if it thinks that the other countries will act, too. Additionally, this indicates that there are two Nash equilibria: either all countries choose to act or all countries choose to exploit. Even though only the equilibrium (act, act) is strictly efficient, the model cannot tell which of the two equilibria will be chosen. Apart from that, in real life, countries have of course more choices. While one country might not contribute at all, another country might reduce emissions by more than the amount that is required from it. On the other hand, it might be that a small country significantly decreases emissions while a big country continues to exploit and thus sets off the small country's achievements.

This type of coordination game might sound simple. So, why has coordination not worked for climate change negotiations so far? One of the reasons might be uncertainty regarding the thresholds and impacts of climate change. This will be investigated in the next chapter.

5. Factors that Change the Game

5.1. The Role of Uncertainty in Climate Change Negotiations

5.1.1. Tipping points

It is widely discussed in science, whether there is a big tipping point in climate change, i.e. whether at some point in time global climate will irreversibly pass over to another climatic state. The reason for the high uncertainty is that first of all, the data available is insufficient to make clear predictions and secondly, it is only possible to model the processes underlying climate change to a certain degree.

In order to find out more about the probability of crossing a climatic tipping point given different levels of global temperature rise, Kriegler et al. (2009) have investigated the beliefs of 43 scientists who are experts in this field with regards to five highly temperature-sensitive systems: the Atlantic meridional overturning circulation, the Greenland ice sheet, the West Antarctic ice sheet, the Amazon rainforest and the El Niño / Southern Oscillation. These systems are seen as good indicators for climatic tipping points because one of their main drivers is global mean temperature and they are known for reacting disproportionately strongly to minor changes.

Even though it may be criticized that expert beliefs can only create scientific knowledge if backed up by facts or theory, it is argued that expert elicitations are increasingly recognized in climate science and have proven to be a useful instrument for collecting and illustrating scientific information. In order to assure a conservative valuation of the data gathered, Kriegler et al.'s study uses an imprecise probability assessment approach, which means that instead of attributing a probability that closest matches the expert's statement, those probabilities that do not align with the expert's belief are excluded. Additionally, the study focusses on the lower end of the experts' probability estimations.

The researchers found out that experts do not consider the crossing of tipping points to be far off, despite the generally high degree of uncertainty concerning the provocation of severe climatic changes. In addition, the study's results suggest noticeably higher probabilities for triggering climatic tipping points than other climate damage valuations do. The lower probabilities for crossing at least one tipping point of the five indicators explained above are estimated to be 0.16 for a global temperature rise of 2-4°C and 0.56 in case of a temperature rise above 4°C, base year being 2000. Nevertheless, the paper emphasizes the considerable uncertainty in detecting critical climate change thresholds.[66]

5.1.2. Uncertainty in Climate Change Negotiations

Although it is obviously clear that climate change is happening, neither the exact magnitude of the impacts, nor a tipping point is clearly assessable at this point in time. For that reason, there is a high degree of uncertainty that also has

[66] Kriegler et al. (2009)

an impact on the countries' decision making processes in climate change negotiations.

A Theoretical Investigation on Uncertainty in Climate Change Negotiations

In the paper *Climate Treaties and Approaching Catastrophes*, Barrett develops a theory that seeks to answer the question whether the fright of triggering a catastrophic tipping point might help countries succeed in enforcing climate treaties and increase their effectivity.

The theory suggests that certainty about the impacts of climate change should have little impact, whereas certainty about the exact threshold should be of critical importance and could turn the game from a prisoner's dilemma into a stag hunt. One important factor is considered to be the cost of global warming. If this is not high enough compared to the cost of acting against it, the game remains a cooperation game, i.e. a prisoner's dilemma. However, if the cost of climate change is high compared to the cost of acting, a self-enforcing agreement that uses the treaty as a device for coordination is possible and can extremely increase the treaty's effectiveness.
Furthermore, the theory claims that the incentive to free ride is highly reduced when the threshold is certain, as marginally exceeding the threshold causes a huge increase in damages, i.e. the change is discontinuous. In contrast, if the threshold is uncertain, slightly crossing the limit having been set only slightly increases the expected damage. Therefore, also the incentive to free ride is only slightly reduced. Consequently, Barrett concludes that a substantial reduction of the threshold uncertainty could help immensely in improving climate change negotiations. As science cannot identify an exact threshold at this point in time, another method that could set such a limit, which is not meant to be a serious proposition by the author but rather a food for thought for the reader, is a doomsday machine that starts a worldwide catastrophe when a certain level of greenhouse gases is in the atmosphere. [67]

Experimental Investigation on the Theory I

This theory was tested in two papers using experimental economics, meaning that countries were represented by people or more precisely by German

[67] For previous sections see: Barrett (2013)

undergraduate students who played a comparable game with real money. In the first game, the 200 participants were divided into groups of 10 students. Each of them received 10 black poker chips worth 10ct each and ten red chips at a value of 1€ each. In every round the participants could decide whether to hand in any number of their chips or whether to hold on to them. One chip handed in is worth 5ct for every participant. In order to make the game a coordination game, the threshold given was that if not at least 150 chips were handed back in total, everyone would lose 15€. This implies that if every participant handed in exactly 15 chips, the 15€ would be saved for everyone in the group.

It turned out that on average, more than half of the participants handed back exactly 15 chips, the mean being 15.1 chips. Knowing this, the game can be compared to a stag hunt game: as long as a player does not think that all the nine others will contribute their stake of 15 chips, there is no incentive to hand in any chips but to take the payoff of 2.75€. Yet, if the player believes that the others will make their contribution, the incentive of 12.50€ to do so as well is significantly higher. Two key insights of this stage of the game were that first of all, the incentive to free ride appears to be considerably less attractive than the incentive to coordinate. In addition, 15 turned out to be a focal point that enabled coordination to succeed, as it assigned a stake to every participant.

In order to test the theory that impact uncertainty has no impact on the results whereas threshold uncertainty is the determining factor, the following rounds of the game have different treatments of uncertainties. Instead of an exact threshold of 150 chips, an interval from 100 to 200 with an expected value of 150 is given and instead of an absolute impact value of 15€, an interval from 10€ to 20€ with an expected value of 15€ is given.

The results in Figure 9 show the probability of catastrophe by treatment. In the treatment with absolute certainty, catastrophe could be avoided 8 times out of 10, whereas the two catastrophe cases are explained to be outliers. In the situation of uncertain impact (I-Uncertainty), it was even avoided 10 out of 10 times. In the case of threshold uncertainty (T-Uncertainty), the probability of catastrophe could be reduced to less than 100% by only 1 of 10 groups and in the event of impact and threshold uncertainty (IT-Uncertainty) by only 3 of 10 groups. The computer programme found out that in the four cases where the probability of catastrophe had been reduced to less than 100%, the threshold was crossed every time.

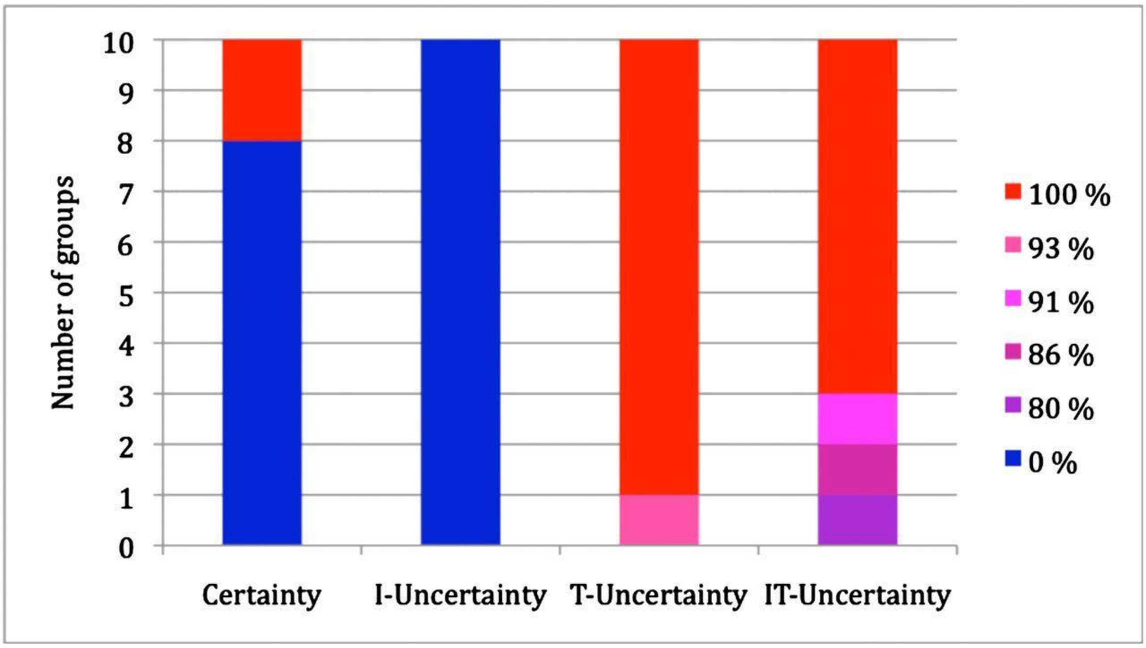


Figure 9: Probability of Catastrophe by Treatment[68]

Looking at the four bars it is obvious that impact uncertainty did not negatively influence the results of the game, while threshold uncertainty always led to a catastrophic failure, meaning that the theoretical assumptions have proved to be right in the experiment.

Figure 10 emphasizes another interesting observation of the experiment. In the treatments with certainty and impact uncertainty, pledges and contributions were close together, with contributions that usually exceeded the pledges, except for two outliers in which the players cheated by making a pledge of 15 but contributing nothing. In contrast, in both situations with threshold uncertainty, the values were largely distributed and the contributions were in most of the cases falling clearly short of the pledges that had been made before.[69]

[68] Barrett and Dannenberg (2012)
[69] For previous sections see: Barrett and Dannenberg (2012)

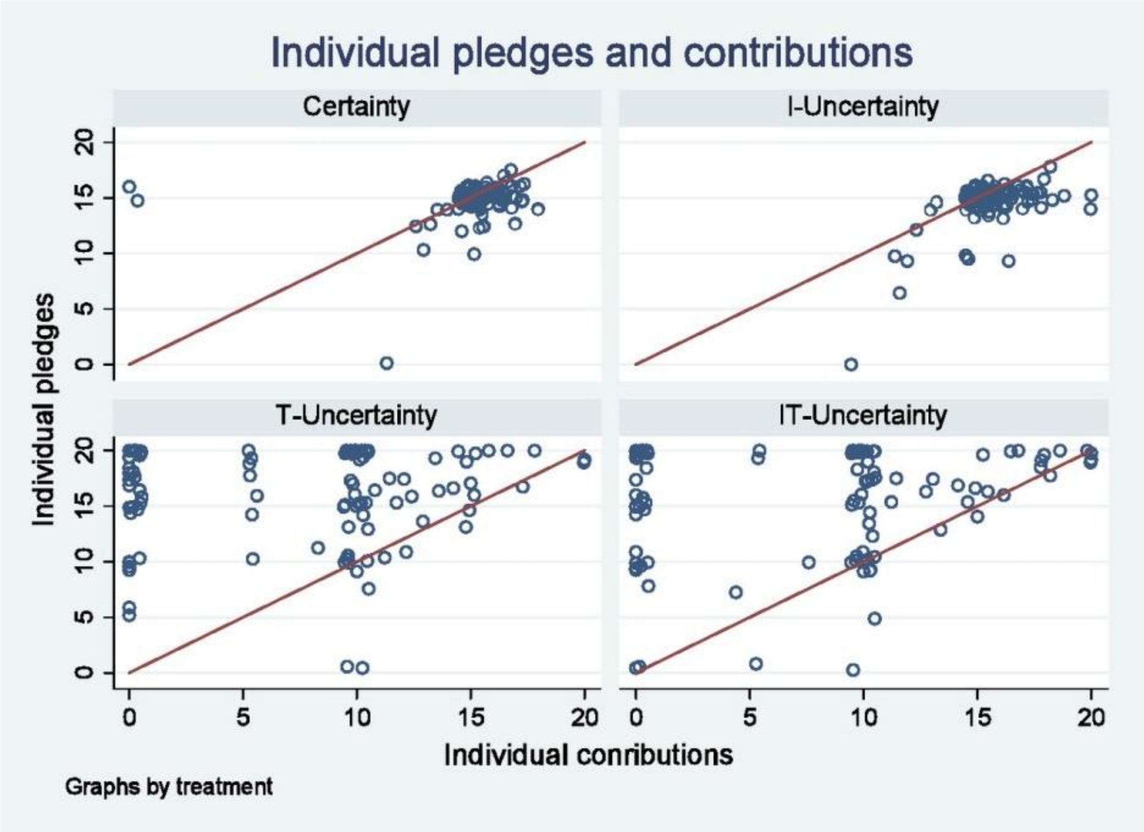


Figure 10: Pledges and Actual Contributions by Treatment[70]

Experimental Investigation on the Theory II

In a second experiment it is tested whether there is a dividing line for threshold uncertainty along which behavior differs significantly. As can be seen in Figure 11, the experiment suggests a dividing line located on the lower end of the uncertainty range. It can be identified that on the left hand side of the dividing line, proposals, pledges and contributions are close together. In contrast, right behind the dividing line, proposals and pledges stay approximately constant but contributions fall short of the pledges by far.

It can be concluded that in case of threshold uncertainty, trends indicate a change in behavior at an early point of the uncertainty interval and a significant decline of contributions made.[71]

[70] Barrett and Dannenberg (2012)
[71] For previous section see: Barrett and Dannenberg (2014)

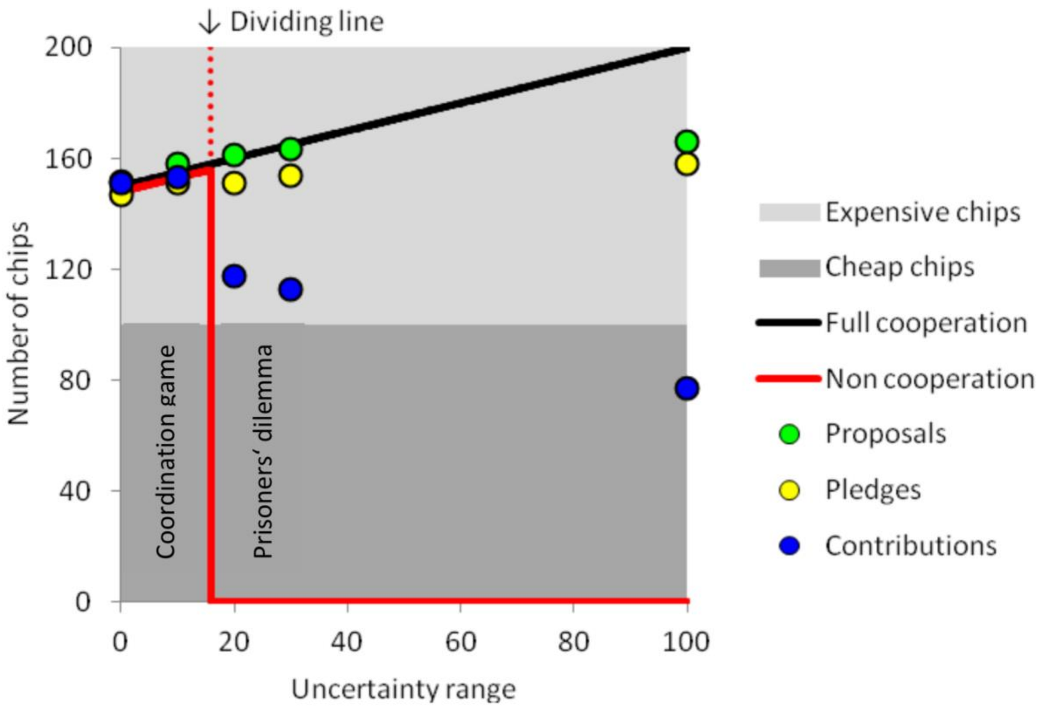


Figure 11: Behavior Change along the Dividing Line[72]

The experiments described support the theory that threshold uncertainty is crucial for the success of climate change negotiations as certainty about the threshold could convert a prisoner's dilemma into a coordination game. However, science is currently not able to make definite predictions about a tipping point and as a doomsday machine is not a suitable solution, other mechanisms are necessary in order to change the climate game.

5.2. Reciprocity Strategies

5.2.1. Tit for Tat

Another way to confront the prisoner's dilemma is adopting an intrinsic strategy of reciprocity, such as tit for tat. This can be useful to achieve cooperation if the game is played an indefinite number of times. The strategy developed by Axelrod in 1984 requires the player to always copy the strategy the other player has played the round before. For example, in the first round, player 1 cooperates in order to escape the prisoner's dilemma. If player 2 then decides to cooperate as well, player 1 will reward player 2 for the cooperation by also

[72] Barrett and Dannenberg (2014)

cooperating again, which results in a better payoff for both. However, if player 2 defaults, player 1 will reciprocate this move in the next round and default as well in order to punish the uncooperative behavior.

One famous example of a tit for tat strategy is the First World War, during which both sides' soldiers in the trenches practiced unspoken armistice. This developed from the consideration that by killing a soldier from the other camp, the wish for revenge would soon lead to the death of an own soldier. This phenomenon got also known as the live and let live strategy.

5.2.2. Tit for Tat in Climate Change Negotiations

This strategy can also be applied to climate change negotiations, as it is believed that intrinsic strategies can help sustain cooperation in international settings. This implies that cooperation occurs if the other parties have cooperated in the past. Yet, if one side defaults at some point in time, this would result in continuously uncooperative outcomes. For example, if the EU started off by playing a cooperative strategy but other major economies would not step in as well, the EU might decide to also switch its strategy to a non-cooperative one, leading to other parties defaulting in turn.[73] This could be relaxed through a tit for two tats approach, in which strategies are only switched if the other party fails to cooperate twice. This means that it pardons misbehavior to a certain degree. Another main concern of tit for tat is that it is not subgame perfect and therefore not a rational strategy for individual players.[74]

Tingley and Tomz investigated how receptive the citizens, being the ones voting for the governments that ultimately decide on a nation's strategy in climate change negotiations, are to reciprocity strategies. Their findings suggest that this type of strategy is unlikely to work in the context of climate change, except if linked to other incentives or implemented in international law. More precisely, in case of the USA it was found that even though a pollution cycle was rather unlikely, as US citizens did not want their nation's emissions to increase collectively with other countries' emissions. Nevertheless, it could be concluded that they were not prepared to play a tit for tat strategy, fearing other countries

[73] For previous section see: Ward (1996)
[74] Barrett (1999)

could free ride, which consequently gives other countries less incentive to cooperate.[75] For that reason, a mechanism against free riding could be a valuable tool to also render reciprocity strategies more attractive in climate change negotiations.

6. Mechanisms to Overcome the Free Rider Effect

6.1. Changing Payoffs

Another option to change a game is to manipulate the payoffs. This can be done by setting incentives that make strategies more or less attractive than before. Matrix 9 and Matrix 10 show one option how the initial prisoner's dilemma payoff matrix could be transformed into a coordination game.

		Rest of the World	
		Act	**Exploit**
Single Country	**Act**	**-1**	**-4**
	Exploit	**1**	**-2**

Matrix 9: Initial Prisoner's Dilemma Payoff Matrix

The initial matrix assumed a cost of -3 for the potential risk of global warming, a cost of -1 for the immediate costs for acting and a payoff of +1 for the benefit from exploiting. Adding a cost for compensation equal to the risk of global warming, i.e. -3, if the country is not willing to act while the rest of the world does act, the payoffs change, as can be seen in the modified matrix:

		Rest of the World	
		Act	**Exploit**
Single Country	**Act**	**-1**	**-4**
	Exploit	**-2**	**-2**

Matrix 10: Initial Payoff Matrix Modified[76]

This transformation overrides the free rider effect, meaning that there is no more incentive for the single country to exploit, given that the rest of the world

[75] For previous section see: Tingley and Tomz (2014)
[76] For a matrix breakdown see Annex: Matrix 3 (Breakdown: Initial Payoff Matrix Modified)

acts, in order to benefit from the other countries' efforts. Therefore, this transformation abrogates exploiting as the dominant strategy for the single country and makes the best response the strategy the other players have chosen as well, i.e. coordinating with the rest of the world. How this result can be achieved and what a suitable compensation could look like has been examined in several papers. The main ideas will be presented in the following.

6.2. Climate Clubs

6.2.1. Clubs as Economic Mechanisms

In his Paper *Climate Clubs: Overcoming Free-riding in International Climate Policy,* Nordhaus investigated the possibility of what he calls climate clubs, groups that work towards a shared goal such as the conservation of a common resource by sharing the associated cost in order to profit from the created benefits, as a mechanism to prevent countries from free riding. He stresses that for two reasons, climate change negotiations are more complex than most other issues. First of all, they are especially concerned with the free rider effect because there is not only an incentive to free ride on the efforts made by other countries but also on the welfare of future generations, which is called a temporal free riding effect. Secondly, the Westphalian dilemma, which significates the fundamentals of international modern law, i.e. sovereignty of all states, their right to self-determination, legal equality and the right to handle their internal activities independent from other states' intervention, makes overcoming the free rider effect extremely difficult.

Clubs are generally required to fulfill four criteria. First, the club's subject has to be a shareable resource of the sort of a public good. Secondly, the cooperative outcome has to be favorable to the participants. Thirdly, parties that do not take part can be left out or penalized and lastly, there is no incentive for the members to leave the club. The similarity of all kinds of clubs is that the members have to contribute their portion to the successful course of the club.

6.2.2. Clubs and Climate Change Negotiations

In the special case of climate change, a climate club is characterized as a pact between countries with the goal to reduce greenhouse gas emissions in a coordinated way. As an enforcement mechanism, Nordhaus proposes an international target carbon price that should serve as a focal point for all participating countries. For example, members of the climate club could impose taxes on carbon, a cap and trade mechanism or a mixture of both in order to achieve a domestic carbon price that is in line with the minimum value set by the climate club. In order to make joining the club attractive, non-members are penalized through import tariffs. In contrast to most other propositions, Nordhaus does not only consider tariffs on goods that are carbon intensive in production and use but general import tariffs imposed on non-participants of the club.

Table 4 shows a numerical example of the mode of functioning of a climate club. It assumes that the USA are in their decision making process whether to participate in a climate club or not, given an international target carbon price of $25 per ton and the participation of all other countries with high income.

	US is participant		US is not a participant	
Penalty tariff rate	0 percent	4 percent	0 percent	4 percent
Abatement	-11.9	-11.9	-0.3	-0.3
Damages	10.7	10.7	7.3	7.3
Trade	0.0	36.7	0.0	-15.6
Net benefits	-1.2	35.5	7.0	-8.6
Net effect of participation			-8.2	44.1

Table 4: Net Effect of Participation for USA[77, 78]

As can be seen, the values for abatement costs are almost 40 times as high if the US participates in the climate club as if it refuses to do so. If the country participates in the climate club, climate damages, which behave proportionately to global emissions, can be reduced more significantly. Therefore, the benefit is $3.4 billion per year higher than if the USA does not participate. Finally, trade, as the only factor being influenced by penalty tariffs, is of course significantly

[77] Values in billions of 2011 US$
[78] Nordhaus (2015)

higher if the nation can benefit from free trade with all the club member states than if it is penalized for not taking part. This leads to net benefits ranging from -$8.6 billion in the case of non-participation and 4% tariff rates to $35.5 billion in the case of participation and penalty tariff. The net effect of participation for the US is therefore $-8.2 billion if no tariffs are imposed on non-participating countries and $44.1 billion if a tariff rate of 4% is applied. The impact of the penalty tariff is therefore $52.3 billion per year. This underlines that the concept of a climate club does only work if there is a strong incentive in the form of a penalty tariff for countries to participate.

6.2.3. Predictions

Predictions about participation levels, given different international target carbon prices and tariff rates, are summarized in Figure 12. The number of participating regions can be read from the y-axis, while the x-axis shows four different carbon prices, each with eleven bars that represent tariff rates from 0% to 10%.

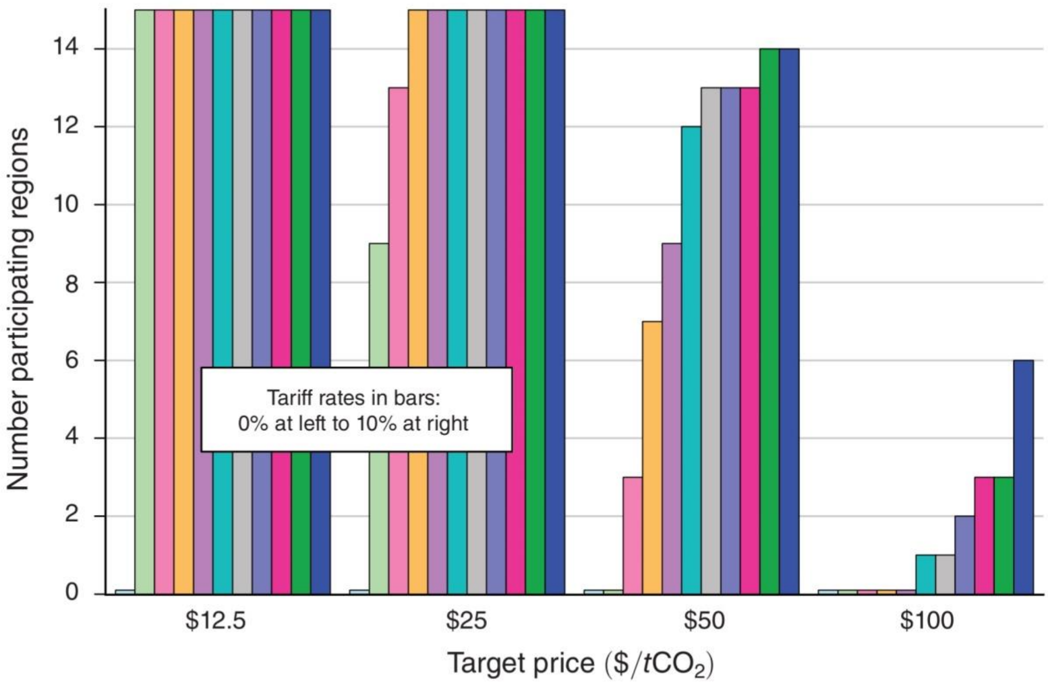


Figure 12: Number of Participating Regions by International Target Carbon Price and Tariff Rate[79]

[79] Nordhaus (2015)

The theoretic calculations suggest that for an international target carbon price with up to $50 per ton, imposing relatively low tariffs on outside states could already lead to a high level of participation. This implies that a situation is generated in which self-interest drives countries to join the climate club and accept important emissions reductions for having access to the trade benefits from being part of the club. Additionally, the study concludes that stable coalitions in a climate club are only possible with trade sanctions against non-members, except for the ones with insignificant abatement.[80]

Notwithstanding the reasonable evidence given in the paper, Nordhaus' theory has also been questioned in some points. While the paper assumes that international trade could be connected to emission reduction commitments, other researchers point out that in case of penalty tariffs, a policy of retaliation could be expected from the penalized countries, which has not been considered in the theory. This could change the former simple game with the only reasonable strategy for countries and therefore the only Nash equilibrium being to participate in the climate club to either a prisoner's dilemma or a coordination game. Another point that has been criticized is that the theory predicts a successful climate club for international target carbon prices with up to $50 per ton. However, this amount is considered to be too small in order to fight severe climate change. Additionally, it would be favorable to have a vast majority of countries acting against climate change instead of single fractions. Finally, it is criticized that Nordhaus builds his theory upon the assumption that countries value trade cooperation more than they value climate cooperation, which might, despite the imparities in success of treaty making processes, not necessarily be the case.[81]

6.3. Linear Compensation

6.3.1. The Concept

Another approach to prevent countries from free riding in climate affairs is presented by Heitzig, Lessmann and Zou. Instead of tying greenhouse gas emission reductions to trade, which does not only hurt the nation being

[80] For previous sections see: Nordhaus (2015)
[81] For previous section see: Barrett (2016)

punished but indirectly also the punishing country, it is proposed to introduce a linear compensation mechanism. This tool measures a country's performance relative to the other participants' achievements instead of evaluating the performance on an absolute basis. This means that if one country does not meet its reduction goals and all other nations have not met them either, i.e. the average underperformance is significantly above zero, the single country will be punished less than if all the other countries had met their emissions reduction goals. Therefore, the punishment for not achieving the individual goals is proportional to the nation's deviation from the average performance of all countries. In this case, the punishment is not given by a trade restriction but by an increase of the following year's emissions reduction target.[82]

There are several reasons for which a method of linear compensation could help with the problems encountered in climate change negotiations. First of all, it can deal with the uncertainty about the difficulty of decreasing greenhouse gas emissions. If it turns out to be easy to do so on the one hand, for example due to technological advances or other factors, and most countries have no issues meeting or exceeding their targets, those countries that underperform or do not put in enough money or efforts will be penalized relatively hard. On the other hand, if it appears to be unexpectedly difficult to decrease emissions by the targets that had been set and the majority of nations fall short of their initial targets, the countries below average are penalized relatively less. Secondly, the countries' performance is evaluated on the basis of a descriptive norm as it compares nations and their success in reducing greenhouse gas emissions with each other. From a social psychology point of view, this ongoing comparison with peers is a factor that can strongly influence an individual's behavior. However, whether the same is true for entire nations is unsure. Another advantage of the linear compensation mechanism is that it is subgame perfect and that the dominant strategy is always cooperating, as the net benefits of defecting are continually smaller than those of cooperating.

[82] For previous section see: Heitzig et al. (2011)

6.3.2. Criticism

Nevertheless, there are some points in Heitzig et al.'s work that can be criticized. One criticism is that perfect information is assumed. This might actually not be the case, as governments usually do not like to put their cards on the table and sometimes even make pledges or promises that they know they will not be able to keep. The biggest threat of the linear compensation mechanism though is a downward spiral of the abatement levels. This is because the evaluation of a member relative to the other nations' performance does not only imply that a country that has underperformed in one period is penalized accordingly, but also that a country that has performed above average in one period will be required less abatement in the next phase. This suggests that abatement levels might turn out to be too low or after some time even out at a certain level.

Finally, the model is limited to nations, even though there can be found influential parties other than the states themselves such as subordinate institutions, big corporations or NGOs. Therefore, the theory's assumption that all players are acting purely rational, which is a frequent criticism of game theory in general, might not be applicable to all of these stakeholders.[83]

Even though the model has some weaknesses and besides does not offer a proposal on how to negotiate the individual emissions reduction targets, it fulfills its purpose of eliminating the free rider effect and could therefore be a valuable tool, in connection with other mechanisms, to give climate change negotiations a new direction and shift the prisoner's dilemma to a coordination game.

7. Choosing the *Right* Nash Equilibrium in a Coordination Game

7.1. Equilibrium in Mixed Strategies

Even though there are mechanisms that might have the potential to change the climate game from a prisoner's dilemma to a coordination game, the battle is still not won. A coordination game has two Nash equilibria, i.e. two situations in

[83] For previous sections see: Dietz and Zhao (2011)

which there is no incentive to deviate, so how will the countries choose between multilaterally acting or multilaterally not acting?

Recalling the initial stag hunt matrix, it can be seen that there are two pure strategy Nash equilibria in the stag hunt game, yet only one of them being strictly efficient.

		Huntsman 2	
		Stag	Hare
Huntsman 1	Stag	5, 5	0, 1
	Hare	1, 0	1, 1

Matrix 11: Initial Stag Hunt

Nevertheless, in order to decide which strategy to choose, the two players can also estimate a probability of the other player opting for "stag" and calculate the expected payoff in mixed strategies.

For the example of the stag hunt game, this means that if huntsman 1 thinks that with a probability p of 50% huntsman 2 will choose to hunt the stag, the expected payoffs V from hunting a stag, respectively a hare are:

V(stag, 0.5) = 0.5 x 5 + 0.5 x 0 = 2.5

V(hare, 0.5) = 0.5 x 1 + 0.5 x 1 = 1.0 .

In this case, huntsman 1 should hunt the stag because the expected payoff of 2.5 outweighs the expected payoff of 1 from hunting a hare.

On the other hand, if huntsman 1 thinks that with a probability p of only 10% huntsman 2 will choose to hunt the stag, the expected payoffs V from also hunting a stag, respectively a hare are:

V(stag, 0.1) = 0.1 x 5 + 0.1 x 0 = 0.5 .

V(hare, 0.9) = 0.9 x 1 + 0.9 x 1 = 1.8 .

In this situation, huntsman 1 will prefer hunting the hare, because the expected payoff of 1.8 outweighs the expected payoff of 0.5 from hunting a stag.

This shows that, if there was a stag hunt game with two Nash equilibria, in order to move the behavior of a population from one Nash equilibrium to another one that is strictly efficient, the players need to have enough confidence that the other players, too, will switch from the non-cooperative to the cooperative strategy and stay there consistently.

7.2. Implications for Climate Change Negotiations

In terms of climate change negotiations, it can be concluded that even if there were mechanisms implemented to successfully make the climate game a coordination game, there is still no guarantee that the countries will opt for the strictly efficient Nash equilibrium, which would be to multilaterally act against climate change even though this would in fact be the best option for all parties. Sustaining the cooperative outcome requires a sufficiently large amount of participants opting for this option in order to ensure the beneficial advantage of the equilibrium. However, making countries leave the inefficient equilibrium involves confidence that the other countries, too, will change their strategy, because unilaterally switching strategy is not beneficial. This is a crucial point as countries in general may not be very trustful towards each other. Additionally, for countries, switching their strategies implies fundamental risks as they cannot know in advance whether other countries will actually comply with their pledges while the cost of switching strategy occurs immediately. For example, if country 1 and 2 both agree to reduce their greenhouse gas emissions by a certain percentage until 2030, country 1 will have immediate costs for the implementation of emissions reduction strategies while it will take until 2030 to know whether country 2 does also comply with the agreement. This might result in a tendency towards lower abatement levels as countries might not want to invest heavily while being unsure about the actual efforts of other countries. To close the circle, if countries think that other countries might think the same, establishing enough trust between the parties in order to sustain the efficient equilibrium seems rather implausible.

8. Characteristics of Successful Climate Agreements

It has been found that developing successful climate agreements is highly difficult for two reasons. Firstly, setting incentives to transform a prisoner's dilemma into a coordination game is challenging if high participation levels as well as high abatement levels should be achieved. Secondly, in a coordination game it is still problematic to move the population towards the cooperative outcome, i.e. the strictly efficient Nash equilibrium. Nevertheless, there have been successful environmental agreements. This raises the question: What distinguishes a successful agreement from the other ones?

8.1. Failure of the Kyoto Protocol

The first step to answer this question is to understand why the Kyoto Protocol is often considered to be unsuccessful in its attempts to reduce global greenhouse gas emissions. Aichele and Felbermayr have analyzed 40 sample countries' carbon dioxide emissions and their carbon footprint. The latter comprises all emissions caused by the residents' consumption of goods, independent of whether these goods are imported goods or produced by the country itself. In contrast, the carbon emissions relevant to the Kyoto Protocol are the domestic emissions, containing all the carbon emissions that have occurred during the production of goods, whether consumed domestically or exported, within the country's territory. Obviously, a country's carbon footprint does not necessarily correlate with its carbon emissions. The resulting difference is called the carbon content of net trade.

The following Table 5 shows the 40 sample countries' carbon trade and emission levels per capita at their initial levels in 1995 and the associated change rates. As can be seen, twelve countries are included that have not signed the Kyoto Protocol. Out of the other 28 countries, 23 have ratified the Protocol in 2002. In 1995, the per capita carbon dioxide emissions varied from 0.88 tons in India and 1.04 tons in Indonesia to 16.24 tons in Australia and even 19.65 tons in the USA. Also the average yearly growth rates vary significantly from 5.34% for China and 4.05% for Indonesia to negative growth rates of -2.91% for Sweden and -3.35% for Denmark. Looking at the carbon dioxide footprints, the tendency is clear: countries with high carbon emissions had a high carbon footprint, too, the correlation coefficient being 0.93. In 1995, India and Indonesia had the lowest per capita carbon footprints with 0.73 tons and 1.09 tons. The highest ones were 19.97, 16.42 and 15.10 tons in the USA, Canada and Denmark, respectively. Therefore, it is even more striking that the correlation coefficient of the average yearly growth rates of carbon emissions and footprint is only 0.42. The average yearly growth rate of the per capita carbon footprints vary from 4.37% and 4.65% for Estonia and Spain to -1.74% for Belgium-Luxembourg and -2.40% for Denmark on the lower end.

Finally, the net carbon dioxide emission imports as a percentage of the domestic emissions are indicated for the years 1995 and 2007, whereof 14 had negative net imports, i.e. net exports, in 1995 and 17 out of 40 in 2007. The net carbon imports can have a considerable impact on a country's carbon footprint. For example, in 1995, Switzerland imported goods that embodied almost the amount of the entire domestic emissions. In 2007, it was even more than 140% of its domestic carbon emissions. Also other countries like France, Sweden, Norway and the Netherlands had imports between 30% and 50% of the domestic emissions in 2007. While the biggest exporters with 20% to 30% were Romania, South Africa, Estonia and Finland in 1995, twelve years later China took the lead with exports of 27.3% of the domestic carbon emissions, followed by South Africa with slightly above 20%.

Additionally, it is found that the levels of growth rates of both, carbon footprint and domestic emissions, vary heavily from country to country. Apart from that, the trade of goods embodying emissions made up for 16% of the entire carbon dioxide emissions in 1995. However, in 2007, this value has increased to 21%. This growth began in 2002, the year when most countries ratified the Kyoto Protocol, being also the year of China's entrance to the World Trade Organization.

Country	Year of ratification	CO_2 emission		CO_2 footprint		Net CO_2 imports (as % of emissions)	
		1995	Avg. yearly growth rate (%)	1995	Avg. yearly growth rate (%)	1995	2007
India		0.88	2.60	0.73	3.39	−17.3	−10.1
Indonesia		1.04	4.05	1.09	2.54	4.9	−10.7
Brazil		1.55	1.32	1.57	1.77	1.3	6.4
China		2.57	5.34	2.27	3.50	−11.7	−27.3
Turkey		2.68	2.57	2.88	1.46	7.6	−4.6
Chile		3.30	2.57	3.60	1.96	9.1	2.2
Mexico		3.34	1.71	3.08	2.67	−7.8	2.3
Argentina		3.65	0.96	3.82	0.27	4.7	−3.0
Portugal	2002	4.61	1.07	5.32	1.56	15.4	21.6
Romania	2001	5.36	−2.35	4.11	-0.20	−23.4	−2.7
Spain	2002	5.60	3.89	5.92	4.65	5.7	14.6
Hungary	2002	5.66	−0.40	5.76	0.30	1.8	9.9
Switzerland	2003	5.84	−0.41	11.57	1.38	98.0	140.9
France	2002	6.14	−0.52	7.16	0.86	16.6	35.8
South Africa		6.69	0.61	5.31	0.60	−20.6	−20.7
New Zealand	2002	7.06	1.80	7.95	1.57	12.6	9.8
Italy	2002	7.08	0.56	7.09	1.57	0.1	11.8
Sweden	2002	7.08	−2.91	7.96	0.10	12.4	57.3
Greece	2002	7.17	2.23	7.62	3.14	6.3	17.1
Slovenia	2002	7.26	0.80	6.46	1.69	−11.0	−2.1
Norway	2002	7.65	0.39	10.14	1.47	32.7	49.2
Slovakia	2002	7.69	−1.17	7.78	0.14	1.2	17.0
Austria	2002	7.78	0.81	9.52	0.53	22.4	18.7
Korea		8.64	1.46	8.48	1.53	−1.8	−1.0
Israel		8.78	0.65	10.12	−0.69	15.3	−0.6
Poland	2002	8.98	−1.14	7.96	−0.86	−11.3	−8.4
United Kingdom	2002	9.18	−0.58	8.89	−0.10	−3.1	2.2
Japan	2002	9.24	0.44	10.62	−0.19	14.9	7.2
Ireland	2002	9.46	1.16	9.52	1.82	0.6	8.1
Russia	2004	10.49	0.62	9.54	1.38	−9.0	−1.2
Germany	2002	10.97	−1.12	11.65	−0.81	6.2	9.9
Netherlands	2002	11.46	−0.38	14.95	0.73	30.4	47.3
Estonia	2002	11.84	1.34	8.38	4.37	−29.2	−2.2
Finland	2002	12.15	0.11	9.66	1.28	−20.5	−9.7
Czech Republic	2001	12.20	−0.20	9.86	−0.22	−19.2	−19.4
Belgium-Luxembourg	2002	12.72	−1.13	12.81	−1.74	0.8	−5.9
Denmark	2002	13.43	−3.35	15.10	−2.40	12.4	25.2
Canada	2002	16.01	0.76	16.42	0.84	2.6	3.4
Australia	2007	16.24	1.48	13.60	1.55	−16.3	−15.6
United States		19.65	−0.23	19.97	0.21	1.6	6.7

Notes: The 40 sample countries ordered with respect to their 1995 per capita emission levels. CO_2 emissions and footprints in tons of CO_2 per capita. Domestic CO_2 emissions are from the IEA. Carbon footprints computed using MRIO approach and approximating RoW I–O tables with the GDP per capita matching method described in the text.

Table 5: Per Capita Emission Levels and Carbon Trade: Initial Levels and Rates of Change[84]

Analyzing the data given, Aichele and Felbermayr come to the conclusion that Kyoto has succeeded in reducing the domestic carbon dioxide emissions of some countries by 7% on average. However, this had finally no positive effect on global emissions because the net carbon import rate has increased by 14% at the same time. It is assumed that in those countries with substantial emissions reductions, corporations were affected by the undertaken measures while the population itself, which is relevant for the nation's footprint, was not. This would mean that the Kyoto Protocol has rather relocated the production of carbon dioxide than reducing it. In addition, the authors conclude that the

[84] Aichele and Felbermayr (2011)

concept of the Protocol to require only some nations to reduce their emissions must have led to a carbon leakage, which might not only have compensated emission savings but even harmed the global climate, because it has imposed additional costs on companies and consumers without leading to the desired improvements in global emission levels. The paper's recommendations for future agreements are to either cover all big economies or to adjust the border taxes in order to make a unit of carbon dioxide equally costly wherever the emissions occur.

One main criticism of the paper is the use of only a limited amount of sample countries. This is due to the fact that the Organisation for Economic Cooperation and Development, which provided the data on which the analyses were based, had sufficient data available for only 40 countries and the time span from 1995 to 2007. Therefore, in order to minimize measurement errors, the study was restricted to this timeframe and nations. However, it would be desirable to also include new data for the period from 2008-2012.[85]

8.2. Montreal versus Kyoto

Even though it has proven to be challenging to come to an agreement that achieves high participation, abatement and compliance levels at the same time, there are nevertheless a few successful international treaties, even in the field of environmental issues. One example is the Montreal Protocol that aimed to reduce the usage of ozone depleting substances. The problem of the stratospheric ozone depletion is fairly similar to climate change. The reduction of the respective emissions can be characterized as global public goods for they are global in the sense that both, ozone depleting chemicals emissions and greenhouse gas emissions, occur in every country, that the entire globe is influenced by these emissions and that dealing with them requires a large amount of countries to cooperate. However, there is a crucial imbalance in the success of the Montreal and the Kyoto Protocol. For this reason, several analyses have been conducted in order to find out which were the factors that favored success or failure of the two treaties.

[85] For previous sections see: Aichele and Felbermayr (2012)

8.2.1. The Montreal Protocol

The Montreal Protocol that has been signed in 1987 originated from some scientists' prediction that CFC emissions could lead to a depletion of the ozone layer by 7%, the potential consequences being more people suffering from skin cancer and eye diseases as well as a productivity decrease in agriculture and fishery. Although these predictions were unsure and could not be proved, the USA along with several other countries decided to limit the amount of CFC being produced and used. Nevertheless, CFC emissions continued to increase as other countries began to increasingly make use of the chemicals and some growing industries, such as the one for computer chips, necessitated higher amounts of the chemicals than before. Therefore, in 1977, the UNEP organized an international conference dealing especially with the ozone layer, recommending negotiating a treaty that would manage the protection of the stratospheric ozone. This was realized in 1985 during the Vienna Convention with a framework that did not impose requirements on the signatories, but should support future negotiations.

Short after, it was discovered that over the Antarctic, the ozone layer had diminished by 40% during the time from 1977 to 1985. This led quickly to the signature of the Montreal Protocol in 1987, which required from the signatory nations a reduction of CFC emissions by 50% and the stabilization of some halons at the levels from 1986 until 1999. The agreement entered into force on 1 January 1989 and its 30 signatory countries covered 83% of total emissions of the mentioned chemicals. Because these requirements soon turned out to be insufficient, the Montreal Protocol was corrected in 1990. Instead of eight chemicals, the list was extended to 20 and instead of halving the CFC emissions, a complete elimination was envisioned. An additional goal was to include more developing countries in the agreement. To achieve this, industrialized nations declared their readiness to make payments to developing countries in order to support them with the incremental costs that would occur when complying with the requirements of the Protocol. Two years later, further adjustments were made, including 74 additional chemicals on the list, phase-out dates for different chemicals and most importantly, measures against non-compliance, including systems for licensing and against illegal trade of the relevant chemicals. Since then, participation to the Montreal Protocol has constantly risen to 197 parties.

8.2.2. Differences between Montreal and Kyoto

Even though the two Protocols appear to have many similarities, there are also some points in which they differ dramatically from one another. First of all, the Montreal Protocol limited the amount of emissions of the relevant chemicals for all counties. The Kyoto Protocol on the other hand included only limits for industrial countries and economies in transition, but not for developing countries. While both Protocols involved differentiated emission limits, those in the Montreal Protocol differed only from category to category whereas the Kyoto Protocol allowed negotiating country-specific limits as well as an adjustment of the base year for transition economies. Additionally, these limits were only set up for the period from 2008 to 2012 in case of Kyoto, in contrast to Montreal where the emission limits were meant as permanent restrictions. The problem of emission leakage that was encountered by the Kyoto agreement was avoided in the other Protocol through banning the import of any goods that promote ozone depletion. Another important factor are side payments, i.e. payments by industrial countries to enable developing nations to comply with the agreement, which was a crucial part in the Montreal Protocol but not in the Kyoto Protocol. Along with trade sanctions against non-participants that were stipulated in Montreal's agreement, these side payments represented a fundamental incentive to comply. This and the perspective that goods produced with ozone-depleting chemicals would anyway not be tradeable anymore with member countries to the Protocol because of the import bans against leakage is also considered to be the reason why this treaty was consistent against free riding. The Kyoto Protocol in contrast imposed no trade restrictions and had, apart from the minimum participation clause, weaker incentives against free riding. In the case of Montreal, the minimum participation was two thirds and at least eleven countries, withdrawal being allowed until four years after the ratification and giving one year's notice. For Kyoto, 55% of Annex I's carbon dioxide emissions and at least 55 ratifying countries were required with the right to withdraw until three years from the moment when the Protocol entered into force, also giving one year's notice.

8.2.3. Implications

Barrett comes to the conclusion that the success of the Montreal Protocol can be accredited to the extremely high levels of participation. These were achieved through a mixture of reward-based incentives in the form of side payments, which guaranteed that developing countries and economies in transition could not be disadvantaged by the agreement, and penalty-based incentives represented by trade sanctions, which together with the minimum participation paragraph created a situation in which not participating was unattractive for no matter which country. A usual problem in international agreements is that the incentives are not credible. In the Montreal case this was not the case due to the economics of ozone protection. The rewards were not only credible for developing countries but also for industrial nations because the benefits from protecting the ozone clearly outweighed the costs from complying with the agreement and supporting the other countries. The trade penalties on the other hand were credible because if they would not be used, a production relocation to non-signatory states would be a probable consequence that would obviously not be in the interest of the agreement. Barrett considered the lack of credible mechanisms to encourage participation to be the fundamental weakness of the Kyoto Protocol, as these limit the sustainable level of cooperation that can be expected internationally as well as the potential advantages from cooperating.[86]

Sunstein on the other hand sees a main difference in the highly differing position of the USA concerning the two subjects, because the USA's participation is considered to be a key driver in international environmental agreements. While the USA's cost-benefit analysis for the reduction of ozone-depleting substances came to the result that the Montreal Protocol was highly favorable to the USA and therefore was strongly supported by the government, the same analysis concerned with reductions in greenhouse gas emissions led to the conclusion that the Kyoto Protocol was unattractive and potentially harming to the nation and for this reason the participation was refused. The paper explains this by stating that for the USA, neither of the two situations is a prisoner's dilemma. With regards to ozone depletion, the country would still

[86] For previous sections see: Barrett (1999)

have enough incentive to comply with the framework of the Montreal Protocol if no other country participated. However, in case of the Kyoto Protocol, the loss from climate change for the USA is assumed to be relatively small compared to other parties such as Africa and India, whereas the US, along with China, would have to bear most of the costs for emission reductions.[87]

Chapter Conclusion: This chapter showed that climate change negotiations can be approximated by a prisoner's dilemma. However, a coordination game has proven to be more favorable on condition that the population can be shifted towards the efficient equilibrium. Even though there have been successful environmental agreements, it turned out to be quite difficult to change the game. First of all, because factors like uncertainty and reciprocity cannot be forced or controlled. Secondly, because mechanisms to overcome the free rider effect are hard to implement.

Situation Analysis: US Quitting Paris Agreement

Chapter Outlook: This chapter will reunite the different elements from climate change negotiations, the USA in climate change and game theory looked at before in order to understand reasons why Trump might have decided to quit the Paris Agreement in a first step. Afterwards, the consequences of a withdrawal for the US, other countries and the future development of climate change negotiations will be examined.

9. Reasons for Quitting

Why politicians take certain decisions is not always clear to the public, especially if underlying analyses are not published in detail. However, in case of Trump's decision to quit the Paris Agreement, speculations can roughly be grouped into five categories.

The first possibility is that Trump does just not believe in climate change. This

[87] For previous section see: Sunstein (2006)

assumption does not sound too farfetched, as statistics have shown that only about one third of the US population considers climate change to be a serious problem. However, this consideration has been refuted by the US Ambassador Haley, stating that Trump believed that the climate was changing and that pollutants were part of the equation[88] .

Therefore, another explanation could be that Trump has another payoff valuation than Obama for example. This would mean that he acknowledges the science of climate change but considers the investments and efforts required from the US as more costly than the future cost of climate change. This assumption is supported by Trump's statement on the Paris climate accord, in which he refers to a study of the National Economic Research Associates that estimated that compliance with the agreement would cost the country almost $3 trillion of GDP and therefore concludes that this burden would put the country in an uncompetitive position and create less benefit for the US than for other countries[89]. However, the Stern Review, a frequently cited work on the economics of climate change, comes to the conclusion that, if countries act immediately and to a sufficient extent, this would be beneficial to all countries, as the findings suggest that the costs of acting could be limited to approximately 1% of global GDP per year, while not acting could cost as much as 5% - 20% of global GDP, depending on the impacts of climate change. Even though these are anticipated to affect many developing countries stronger than industrial nations, the review emphasizes that every single country will suffer from global warming.[90] Nevertheless, from a game theoretic point of view, the high degree of uncertainty connected to the climate change issue speaks in favor of this explanation, as the payoff valuation does highly depend on the information available to the parties, their rationalities, as well as on their personal beliefs and reservations.

A third explanation can also be found in the same statement of Trump's, in which he denotes the US would remain the most environmentally friendly country in the world, independent of its commitment or withdrawal from the Paris Agreement. If this was true, game theory suggests that the withdrawal should not make a big difference if the USA's efforts were still visible to other

[88] Cf. CNN (2017a)
[89] Trump (2017)
[90] For previous section see: Stern (2007)

countries. Yet, Trump's plans to cancel carbon dioxide emissions reductions and other climate related regulations[91] might raise doubts how this should be manageable.

Finally, Trump might envision minimizing the USA's financial contributions and retaining a high degree of flexibility while free riding on the efforts of others. This could on the one hand be the other countries that still fulfill their parts, which represents a fourth explanation. This would mean that the Trump administration is convinced that the other countries will manage to avert catastrophic consequences from global warming without the support of the US. On the other hand, the explanation might be a free riding effect on future generations. This would mean that the administration was consciously accepting that future generations would suffer from global climate change because the current generations were not willing to abstain from the benefits of exploitation, which ultimately describes the tragedy of the commons and leads back to the prisoner's dilemma.

10. Consequences

For the US, there would most probably be beneficial short-term consequences as the country could free ride on other nation's efforts and elaborate a competitive advantage compared to the other countries that choose to commit to climate protection. Therewith, additional economic benefits could be created.

Nevertheless, this behavior could in the long run undermine the beneficial impacts of the agreement, especially if the theory of a climate tipping point turned out to be true and the world did not succeed in avoiding the threshold because of lacking commitment from the USA. The scientific impacts of climate change would also hit the US. Figure 13 shows a map of worldwide carbon dioxide emissions in 2015. The size of the dots is proportional to the nation's carbon emissions and the black color indicates that the nation is a signatory of the Paris Agreement, while the red color is used for those countries that have not signed or plan to withdraw.

[91] CNN (2017a)

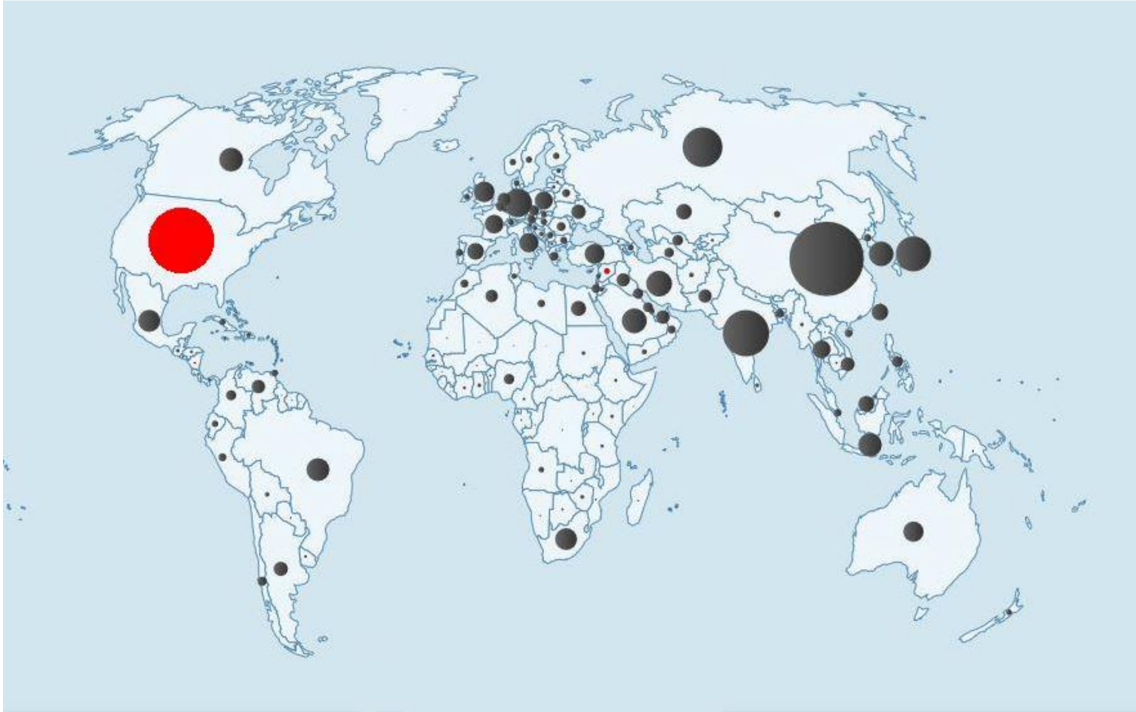


Figure 13: Global CO2 Emissions of Countries in and out of the Paris Agreement[92]

As can be seen, a withdrawal of the US from the Paris Agreement could have a huge effect on the success of the agreement, as those of Nicaragua and Syria are almost negligible and the rest of the world has signed. Knowing that the US has a crucial position in climate change negotiations, the threat is that other countries might change their strategy as a response to the USA's decision.

It is clear that if the climate game was a pure prisoner's dilemma, the withdrawal should not make a change, as all countries should limit their efforts to what is absolutely necessary. On the other hand, if the climate game was a pure coordination game, the withdrawal should have a fundamental impact on climate change negotiations, because the efficient equilibrium is only beneficial to all parties if a vast majority opts for it. This could be endangered if such an important role model takes back its commitment. Although the other G20 parties announced to still adhere to their pledges[93], it can be assumed that the withdrawal of the second largest emitter of carbon dioxide might leave smaller countries discouraged questioning the worthiness of their efforts.

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[92] Own illustration based on 2015 values from: Global Carbon Atlas (2016)
[93] BBC (2017)

Another possibility is that this motivates the other countries to endeavor even more in order to compensate for the losses in progress due to the USA's withdrawal. However, even though some US states are trying to absorb the losses, it might proof not very plausible that other countries are willing to commit even more.

A further possibility could be that some countries start individually imposing trade restrictions on the US in order to punish the nation for not participating in the Paris Agreement. However, it could be expected that the US would then in its turn impose taxes. Therefore, this would only be an option for countries that do not depend on exports and imports from the US or that it can substitute these transactions, for example through trade treaties with other states. This, however, would depict that the Paris Agreement lacks a mechanism to prevent countries from free riding, such as a climate club or a linear compensation mechanism. Implementing such a mechanism has been found to be challenging for a group of negotiating nations. Yet, for single countries, this appears to be almost impossible without strong alliances.

One final possibility is that countries play some kind of reciprocity strategy. This would mean that a withdrawal of the USA could encourage countries to restraint from ratifying the agreement or to just not meet the pledges. In a broader sense, this implies that a withdrawal, or even the already made announcement, could destroy the trust between the parties. For it takes several years to see whether the other nations hold on to their pledges, it might be that parties now take an even more conservative approach to investing in climate protection. This could in total lead to a slowdown in a process in which a strong acceleration would be needed.

> *Chapter Summary: From this chapter it can be concluded that Trump's decision to withdraw from the Paris Agreement was most probably due to a strong incentive to free ride or due to a payoff valuation different from Obama's. However, the assessment of the exact consequences for the US, other countries and the future development of climate change negotiations cannot be finalized outright.*

Conclusion

Although several explanations for the USA's decision can be found, the most probable being free riding incentives or a change in the payoff valuation, most game theorists would probably say that a withdrawal of the USA from the Paris Agreement should not have a huge impact on climate change. Not because they believe that the actions of a single country, even as big as the US, had too little influence, but because they argue that the Paris Agreement, just like its predecessors, should not have much impact on global warming. This is because international agreements do usually not manage to achieve high participation, high compliance levels and ambitious requirements at the same time[94]. This also applies to the Paris Agreement. Apart from the fact that scientists point out that the requirements will probably be too low to effectively tackle the problem of climate change, at least if the countries' pledges are not significantly tightened every five years, especially in the face of a possible threatening tipping point, the USA's plan to withdraw from the agreement proves that it lacks a mechanism to enforce participation. Additionally, it cannot yet be assessed whether the signatory states will comply with all of their pledges. Nevertheless, as there is no chance to observe the counterfactual, it cannot be definitively evaluated whether this is true or whether the world would do significantly worse without the agreement.

The game theoretic findings presented in this thesis suggest that, as long as the climate game can closest be modelled as a prisoner's dilemma, the success of the Paris Agreement should be unaffected by a withdrawal from the US. However, if any factors, such as new scientific insights that give more certainty about the dangerous threshold of temperature warming, will shift the game towards a coordination game at some point in time, a withdrawal of an important player could make it hard to convince other countries to opt for the efficient equilibrium, i.e. strongly acting against climate change.

Increasing the efficiency of the Paris Agreement through mechanisms like climate clubs, which could be done with the help of supplementary regulations or treaties, would also be rendered substantially more difficult if the USA quitted

[94] Cf. Barrett (2016)

the agreement. This is due to the fact that the US is one of the leading economies in the world and requiring countries inside the Paris Agreement to impose taxes and in turn also accept taxes imposed by the US, seems rather impossible.

Still, as Trump emphasized the USA were disadvantaged and weakened by the Paris Agreement compared to other nations like China that could benefit from it, it might be concluded that he is afraid of other countries free riding on the USA's efforts. This fear, however, could effectively be eliminated through a mechanism like linear compensation. Implementing such a mechanism could help make the agreement to be perceived as fair and safe against free riding from other countries. This could possibly increase the countries willingness to adhere to the agreement and put in efforts. Therefore, this could also prevent the US from ultimately quitting the Paris Agreement.

The last game theoretic aspect to be highlighted in this context is the concept of reciprocity. Even though other countries will most likely not react to a withdrawal of the US by actively choosing a reciprocity strategy like tit for tat, the most plausible threat of this event might be that the trust between the countries gets lost and makes other nations feel unsure about their efforts and react, consciously or unconsciously, by reducing them. This could, in the worst case, lead to a global slowdown in climate protection.

To sum it all up, it can be concluded that from a game theoretic point of view, although many variables are still unclear, there is a chance that a withdrawal of the US from the Paris Agreement could have some effect on the future of climate protection. However, further research would be required in order to assess the extent to which countries react to the decisions of other countries and which variables most influence their reactions. For example, it could be investigated whether poor countries are more impressed by actions of the US than rich ones and therefore react stronger or whether those countries that will be least affected by climate change are more responsive to the example given by the US than those that are strongly affected. Another interesting question to be examined is whether the announcement of the other G20 nations to consequently stick to their commitments could compensate for the withdrawal of the US. Finally, it has to be pointed out that, although game theory can help to gain new insights into the topic of climate change negotiations, other tools and approaches should be considered as well.

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List of Illustrations

Annex

Matrix 1 (Breakdown: The Climate Game, Payoffs Prisoner's Dilemma)

		Rest of the World: Act	Rest of the World: Exploit
Single Country	Act	Risk: 0 Cost: -1 Benefit: 0 Sum: -1	Risk: -3 Cost: -1 Benefit: 0 Sum: -4
	Exploit	Risk: 0 Cost: 0 Benefit: 1 Sum: 1	Risk: -3 Cost: 0 Benefit: 1 Sum: -2

Matrix 2 (Breakdown: The Climate Game, Stag Hunt)

		Rest of the World: Act	Rest of the World: Exploit
Single Country	Act	Risk: 0, 0 Cost: -3, -3 Benefit: 0, 0 Sum: -3, -3	Risk: -6, -6 Cost: -3, 0 Benefit: 0, 1 Sum: -9, -5
	Exploit	Risk: -6, -6 Cost: 0, -3 Benefit: 1, 0 Sum: -5, -9	Risk: -6, -6 Cost: 0, 0 Benefit: 1, 1 Sum: -5, -5

Matrix 3 (Breakdown: Initial Payoff Matrix Modified)

		Rest of the World: Act	Rest of the World: Exploit
Single Country	Act	Risk: 0 Cost: -1 Benefit: 0 Compensation: 0 Sum: -1	Risk: -3 Cost: -1 Benefit: 0 Compensation: 0 Sum: -4
	Exploit	Risk: 0 Cost: 0 Benefit: 1 Compensation: -3 Sum: -2	Risk: -3 Cost: 0 Benefit: 1 Compensation: 0 Sum: -2