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„On the Influence of Voters in International Environmental Bargaining“

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1 Introduction

Global warming and climate change are arguably the most important questions of the 21^{st} century. The human race is faced with the threat of extinction of its habitat and is slow in finding solutions to cooperatively deal with this problem. Game theory as a study of strategic interactions is a perfect tool for the analysis of such questions. There is a growing amount of literature on the effects of global warming on economies and growth, as well as strategic game theoretic analyses that examine how best to find cooperative solutions. International environmental agreements (IEAs) are a special focal point, especially in light of the global climate conferences happening on a regular basis which find growing medial attention.

The aim of this thesis is to extend the existing literature on international environmental agreements, by focusing on the effects voters can have on the bargaining process. There have been many analyses of IEAs which focus on different aspects of the agreement. Some of the questions asked include the optimal number of signatory countries, the effect of the formation of climate clubs on the agreement or how best to devise transfers. However, the political economics aspect of voters as players has so far received little attention. This thesis therefore gives new insights as to how voters can affect IEAs. The aim is to move the focus away from the seemingly distant international bargaining setting and back to the individual voter.

This thesis follows the paper by Buchholz et. al. (2005). The model specification is taken from the paper and solved for a specific damage function. The analysis in the paper is then extended to include a further model of voting and ratification, to better understand how voters may influence the international bargaining process in the context of international environmental agreements. In total, three models will be presented and their results compared to each other to determine which setting is most beneficial for the voters.

The first model describes the non-cooperative situation without bargaining for an international agreement. In this model, countries decide on their ideal abatement quantities individually. In the second and third model we include the international bargaining game. These two models differ regarding the order of movement of the actors. In the second model, or election game, the voters move first and elect their preferred governments. After the governments have been elected, the governments negotiate an international agreement. In the third model, or ratification game, the governments move first and negotiate the international agreement. The agreement must then we ratified by the voters in the home country. The games are solved for the Nash Equilibria and Nash Bargaining Solution.

The main results of the paper shows that voters are slightly better off in the ratification game, as they are never worse off than in the non-cooperative situation, while they will be worse off than in the non-cooperative situation for some payoffs in the election game. The exact payoffs also depend on the exogenous spillover parameter.

2 Related Literature

The topic of international climate negotiations has been widely covered in the literature. Some examples include: the optimal number of signatory countries (Barret 1994), the effects of climate clubs (Nordhaus 2015), ratification constraints (Köke, Lange 2017), side payments (Barrett 2001), transfers (Bayramoglu and Jacques 2011) and comparisons between IEAs on a local and international level (Kroll and Schogren 2008). Some papers move towards political science and philosophy, discussing the political and social effects of agreements and the fairness of their contents (Binmore 2014). Other papers examine the components of the contracts themselves (Barrett 1998). Both purely theoretical models with different game theoretic approaches and combinations with agent based modeling and numerical or data analysis can be found (for example Sælen 2016).

The analysis of international climate negotiations goes back to the tragedy of the commons described by Garrett Hardin (1968). He states that the commons will be exhausted for individual gain. Global warming and climate change can be seen as an example of the tragedy of the commons, where the earth's resources represent the commons which are being depleted for individual gain, instead of serving all. Elinor Ostrom (1990) discusses the tragedy of the commons in more detail and describes some of the shortcomings of Hardin's model. She states that the tragedy of the commons can be overcome by cooperative institutions.

However, as Barrett (1994) states, international contracts must be self-enforcing. This means that countries must want to join the agreement voluntarily, because it is more beneficial for them to take part in the agreement than to opt out. This is necessary since there is no institution that is capable of enforcing such a contract globally. The success of the agreement therefore depends on the willingness of the individual countries to join.

What has yet to be discussed in more detail in the literature is the influence of voters in international environmental agreements. Most models focus on governments as negotiating countries, but do not take voters into account. The closest paper to this thesis is from Buchholz et. al. (2005) and examines the effect voters can have on international agreements. In their paper, voters can elect governments which then negotiate the international agreement. They find that voters have an incentive not to vote for their own preferences, but for governments that will improve their countrys' bargaining position on the international level. In this thesis the focus on the voter's position and bargaining power will be extended by including a second model precicely for the purpose of analysing the changes to voter payoffs if the order of movement in the bargaining game is changed.

Other papers that are close to this thesis are Kroll and Schogren (2008) who discuss a two-level game scenario which encompasses the international and domestic levels. They state that domestic constraints affect the results of the international bargaining scenario and use an ultimatum game set-up to model the bargaining process on the international level. The main difference to this thesis is that the Nash Bargaining Solution is used as a methodology and a further model is presented for comparison, which emphasises the voter position.

Concerning the ratification aspect of the model, a similar paper is from Köke and Lange (2017). They look at the ratification threshold for international agreements, but do not include a two-level game or voter influence. The main insight from their paper is that countries will only ratify the agreement up to the point where a certain minimum requirement threshold is reached. Once it has been reached, no more countries will ratify the agreement as they can free ride on the gains without having to agree to the commitment. They look at a large number of ratifying countries and their paper does not specifically include voters in the analysis.

The median voter theorem, which is applied in this thesis, is widely used in political economic literature and was developed by Black (1958), Downs (1957) and Bowen (1943). Holcombe (1989) describes how the median voter model can be used in public choice theory. The median voter theorem is most effectively used in a majoritarian election setting. In this setting, the median voter decides the outcome of the election. Politicians therefore focus on attaining the median voter's vote. In this thesis, the median voter will decide between an agreement entering into force or not. This is a simple choice between two clear options. As the agreement can either be accepted or rejected, the setting is as in a majoritarian election system. The median voter theorem also requires single-peaked preferences, which means that preferences must be rankable. In this thesis, the voters clearly prefer one outcome over the other, which is also necessary for the game theoretic analysis, as it ensures that preferences are transitive.

This thesis adds to the existing literature by placing a greater emphasis on the influence of voters in the international bargaining process. The focus of the analysis is to explain to what extent considering voters in the bargaining process changes overall results and payoffs. It also aims to explain at what point in the bargaining process the voters have the most influence. We therefore compare the situation where voters move first and elect candidates in the initial stage, to a setting where the voters move last and choose between ratifying the agreement or not. The aim is to achieve the highest welfare for the voters and to see in which setting this can best be achieved.

3 The Model

3.1 Definitions and Methodology

This thesis analyses an international bargaining scenario which can be compared to a classic prisoner's dilemma situation, where the dominant strategy is to defect and therefore does not lead to the best possible outcome. To find the optimal solutions of the games, we solve for the Nash Equilibria (NE) and the Nash Bargaining Solution (NBS) of the games presented in the following chapters. Before the specific games are introduced, a general overview of the methodology is given.

The solution concept of finding Nash Equilibira and the Nash Bargaining Solution goes back to the papers of Nash (1950), Nash (1953) and Binmore et. al. (1986). The definition of the concepts are as follows: A strategy profile $s = (s_1, ..., s_I)$ constitutes a Nash Equilibrium of a game if for every $i = 1, ..., I$ it holds that $u_i(s_i, s_{-i}) \geq u_i(s'_i, s_{-i})$, where u_i describes a utility function. A Nash Equilibrium is therefore given if for any strategy of player two, there is no other strategy that allows player one to receive a higher payoff. The Nash Equilibrium is therefore the best response to another player's chosen action in equilibrium.

The Nash Bargaining Solution is defined as solving the optimisation problem:

$$max_{u_1,u_2}(u_1 - d_1)(u_2 - d_2) \tag{1}$$

subject to $(u_1, u_2) \in U$ and $(u_1, u_2) \geq (d_1, d_2)$. If U is compact and (1) continuous, an optimal solution exists. (1) must be strictly quasi-concave to ensure a unique solution exists. The Nash Bargaining Solution therefore compares the utility of a chosen strategy for two players relative to the utility of their default or outside options and maximises the difference between them. The joint surplus of this maximisation problem is equally distributed between the players. In the games presented in the following sections, transfers ensure that gains are distributed equally between the two countries.

The Nash solutions require four axioms to be fulfilled: (i) symmetry, (ii) pareto optimality, (iii) independence of irrelevant alternatives and (iv) invariance to equivalent utility transformations (Osborne and Rubinstein 1994). These four axioms determine a unique solution for the maximisation problem. All axioms hold for the models in this paper.

Environmental protection is a classic prisoner's dilemma situation, where the cooperative outcome, which would give the highest aggregate welfare for individuals, will not be achieved by a Nash Equilibrium, as individual interests interfere with the common interest. The games in this thesis can be compared to a simple prisoner's dilemma setting where there is a dominant strategy that leads to an inefficient outcome. In the models in this paper the choice is not between confessing or lying, but between agreeing to the international agreement or not. Countries would receive higher payoffs if both agree, but due to the costs of implementing the agreement, free riding is an attractive alternative and causes countries to defect from the agreement. The optimal individual action of choosing to defect therefore leads to a sub-optimal collective payoff. The question remains how we can design a bargaining situation where the agreement leads to the highest possible outcome within this prisoner's dilemma situation.

3.2 Model Set-Up

The aim of this thesis is to specifically look at the effect voters in a country can have on the bargaining outcome in international environmental agreements. The analysis will compare the following three models:

(i) In the first model, we look at the non-cooperative solution without any international bargaining. Here we determine the non-cooperative values, which act as a threat point in the following two bargaining models.

(ii) In the second model, we have bargaining on the international level. The voters move first and elect their preferred governments before the international bargaining game starts. This scenario will be referred to as the election game.

(iii) In the third model, there is also a bargaining game on the international level. Bargaining takes place first and voters must ratify the agreement in the last stage of the game for the agreement to enter into force. This will be referred to as the ratification game.

Scenario (i) only has the domestic level, as no international bargaining takes place. For scenarios (ii) and (iii) the game is a two level game comprising a domestic and an international level. In the domestic game, the players are the voters who elect governments or ratify the international agreement. On the international level, governments are the actors who negotiate the international agreement. Both games are simultaneous move games with incomplete information and are described further below.

The election game is based on the paper by Buchholz et. al. (2005). The model presented in their paper is recalculated using a specific damage function and the outcome is compared to the new ratification game model. Buchholz et.al. (2005) use the following model specification in the paper:

$$V_{in}^g(x_{in}, x_{jn}) = x_{in} - \theta_i^g D(x_{in} + s x_{jn})$$

where x_{in} denotes the country's domestic product, D is a function for environmental damage, s denotes the spillover parameter, i and j denote two different countries A and B and θ_i^g describes the type of government of country i. The damage function D determines by how much the domestic product is reduced due to environmental degradation. If θ_i^g is low, the payoff remains high, if θ_i^g is high, the payoff is reduced.

Buchholz et. al. (2005) do not specify a functional form for the damage function. In this thesis the model is solved using a quadratic specification, as this specification is generally accepted in the existing literature. The action set for the game is denoted by the set $A \subseteq \mathbb{R}^2$. The set must be compact and twice continuously differentiable to ensure that a unique solution exists. This is the case for the quadratic specification and allows us to find a maximum point of the function which will determine the unique solution. With the specific function it is possible to test Buchholz's results. Furthermore, an analysis of specific magnitudes and comparisons to the second model are possible. Specifying the function D as a quadratic function we obtain:

$$V_{in}^g(x_{in}, x_{jn}) = x_{in} - \theta_i^g(x_{in} + sx_{jn})^2.$$

The non-cooperative government payoffs of country A and B are then denoted as follows:

$$V_{An}^g(x_{An}, x_{Bn}) = x_{An} - \theta_A^g(x_{An} + sx_{Bn})^2$$

$$V_{Bn}^g(x_{An}, x_{Bn}) = x_{Bn} - \theta_B^g(x_{Bn} + sx_{An})^2.$$

The parameter θ is chosen from a uniform distribution, $\theta \sim U[0, 1]$. θ_i^g denotes the government type, x_{An} and x_{Bn} describe the negotiated quantities and $s \in [0, 1]$ reflects the spillover parameter from the respective other country. The parameter s is given exogenously, all other parameters are endogenous to the model.

The parameter θ describes the different valuations of the benefit derived from a certain abatement quantity for different countries. A lower level of θ means that the country does not feel the pollution as strongly and therefore the overall payoff is higher. This can be interpreted as citizens not caring as much for the environment, or that they do not feel the effects of pollution very strongly in their country. A high level of θ means that overall payoffs will be lower. Countries may feel the effects of pollution more strongly or care more about the environment than countries with a low θ. Countries with a high θ may therefore be more likely to accept higher costs of abatement, as they stand to gain more than countries with a low θ.

The exogenous parameter s defines the spillover effect of pollution. In this model specification the spillover effect will always be negative. For the effect to be positive, s would have to be allowed to take negative values. An example of a spillover effect is air quality. If one country pollutes the air within its borders, other countries in the surrounding area also suffer from worse air quality, as wind will blow the contaminated air across borders. Another example of a negative spillover effect is water contamination. The water cycle is not limited to one country either and does not stay within borders. In this model, a high value of s means that overall payoffs are reduced. This reflects the negative effect of the spillover.

3.3 The Non-Cooperative Solution

To be able to solve for the Nash Bargaining Solution in the following models, we first need to determine the threat point (d_A, d_B) of the game. This is done by solving for the non-cooperative solution of the game, where there is no interaction between countries. No bargaining on the international level takes place in this scenario. Countries choose their abatement levels individually, only according to their own preferences and do not take the actions of the other country into account. Buchholz et. al. (2005: 189) also consider this scenario and call it the "isolationist" option. They find that the isolationist government takes a greater interest in the environment than the cooperative government, meaning that they will advocate higher levels of abatement. The two types of governments converge to each other as s approaches its boundary values of 0 and 1.

Using the equations given by Buchholz et. al. (2005) and adapting them to the specific quadratic function, the non-cooperative government payoffs of country A and B are denoted by

$$V^g_{An}(x_{An}, x_{Bn} \mid \theta^g_A) = x_{An} - \theta^g_A(x_{An} + sx_{Bn})^2 \tag{2}$$

$$V^g_{Bn}(x_{Bn}, x_{An} \mid \theta^g_B) = x_{Bn} - \theta^g_B(x_{Bn} + sx_{An})^2. \tag{3}$$

The payoffs are symmetric for voters and governments. The difference in the payoffs is defined by the voter and government types, given by θ^h and θ^g respectively. To find the Nash Equilibrium of this game, we want to find the optimal quantities (x^*_{An}, x^*_{Bn}) such that

$$u_A(x^*_{An}) \geq u_A(x_{An}, x^*_{Bn}) \quad \forall x_{An}$$

$$u_B(x^*_{Bn}) \geq u_B(x_{Bn}, x^*_{An}) \quad \forall x_{Bn}$$

where u^*_A and u^*_B are utility functions that represent the respective preferences of countries A and B, and x^*_{An} and x^*_{Bn} are the optimal allocations of non-cooperative abatement quantities. The quantities x^*_{An} and x^*_{Bn} are chosen such that they are best responses.

To find x^*_{An} and x^*_{Bn} we solve for the NE of the game. We therefore find the maximum point of the function by determining the first order conditions. These are given by

$$\frac{\partial V^g_{An}}{\partial x_{An}} = 1 - 2\theta^g_A(x_{An} + sx_{Bn}) = 0$$

$$\frac{\partial V^g_{Bn}}{\partial x_{Bn}} = 1 - 2\theta^g_B(x_{Bn} + sx_{An}) = 0.$$

To check that the required functional properties hold, we find the second order conditions and check that they are less than zero. They are given by

$$\frac{\partial^2 V^g_{An}}{\partial x^2_{An}} = -2\theta^g_A < 0$$

$$\frac{\partial^2 V^g_{Bn}}{\partial x^2_{Bn}} = -2\theta^g_B < 0.$$

The second order conditions show us that a maximum point of the function exists for all positive values of θ^g_A and θ^g_B. As θ is bounded between 0 and 1 as defined above, all values of the function will be negative.

To find the optimal quantities x^*_{An} and x^*_{Bn} we set the FOCs equal to 0 and solve for x_{An} and x_{Bn}. This gives the equilibrium values of

$$x^*_{An} = \frac{\theta^g_B - s\theta^g_A}{2\theta^g_A\theta^g_B(1-s^2)} \tag{4}$$

$$x^*_{Bn} = \frac{\theta^g_A - s\theta^g_B}{2\theta^g_A\theta^g_B(1-s^2)}. \tag{5}$$

These values denote the non-cooperative solution quantity for country A and country B respectively and determine the threat point of the following games. The payoffs of the optimal choices in the other scenarios must be higher than the threat point to be chosen by the actors. If they lie below the threat point, the threat point is the default solution that will be chosen as it gives a higher payoff.

To find the specific payoffs for this scenario, we take x^*_{An} and x^*_{Bn} from equations (4) and (5) and insert them into equations (2) and (3), which gives the payoffs of country A and B respectively. Payoffs for governments and voters are symmetric and only differ regarding the type. We therefore only show the government payoffs which are given by

$$V^g_{An}(x^*_{An}, x^*_{Bn} \mid \theta^g_A, \theta^g_B) = \frac{\theta^g_B - 2s\theta^g_A - s^2\theta^g_B}{4\theta^g_A\theta^g_B(1-s^2)} \tag{6}$$

$$V^g_{Bn}(x^*_{Bn}, x^*_{An} \mid \theta^g_A, \theta^g_B) = \frac{\theta^g_A - 2s\theta^g_B - s^2\theta^g_A}{4\theta^g_A\theta^g_B(1-s^2)}. \tag{7}$$

These payoffs determine the threat point for specific values of θ. The graph in Figure 1 below shows the distribution of the payoffs for country A when we fix $s = \frac{1}{3}$. From top to bottom the three curves show values for $\theta_B = 1$, $\theta_B = 0.5$ and $\theta_B = 0.1$. We see that the payoffs decrease for all values of θ_B as θ_A increases. For higher values of θ_B the payoffs decrease more slowly. Country A therefore receives the highest payoffs for a high value of θ_B paired with a low value of θ_A. This is because country A will agree to lower abatement quantities and country B to higher quantities in this combination. Country A benefits more than country B due to its lower type. Since payoffs are symmetric, country B receives the highest payoffs in a situation where θ_A is high and θ_B is low. Similar results can be observed when we fix $s = \frac{2}{3}$. The only difference is that payoffs decrease more quickly.

Since countries do not take the other country's actions into account in the non-cooperative solution, the spillover effect is the only link between the two countries, as no transfers exist

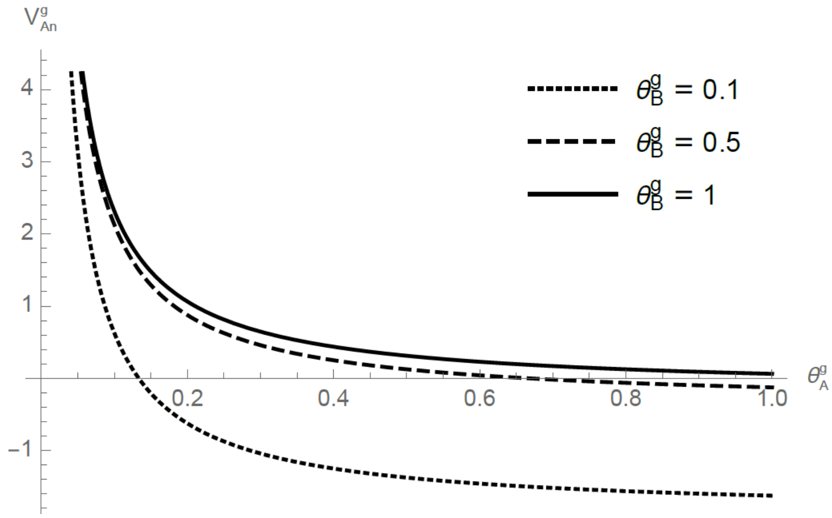

Figure 1: Non-Cooperative Government Payoffs for Country A

as in the later models. The government type is the defining factor in fixing quantities. A high type means that the country feels the effects of pollution more strongly and will decide to take greater action to combat pollution. The country with the low type benefits from this due to the spillover effect, but will not have a high incentive to prevent pollution itself. The country with the lower type with values of θ_i close to zero will therefore benefit and receive higher payoffs as it can free ride on the country with the higher type. This effect increases as the value of s increases, as the spillover effect is stronger for higher values of s.

In the following chapter we will find the cooperative solution with international bargaining and compare the present results to the cooperative situation, where transfers are included to ensure an equal division of the overall gains achieved through the agreement.

3.4 The Election Game

3.4.1 Describing the Game

The election game is similar to the non-cooperative game, but includes bargaining on the international level. Countries now take the actions of the respective other country into account when devising their strategies and no longer decide in isolation. In the election game, voters elect governments in the first stage of the game. The elected governments then negotiate over the cooperative quantities x_{Ac} and x_{Bc} for the agreement on the international level. The optimal solution for the international bargaining process is determined by the Nash Bargaining Solution, which maximises the product of the utilities of the two countries with respect to the threat point. Transfers are included to ensure an equal division of the overall gains. The game is described in the game tree in Figure 2 below.

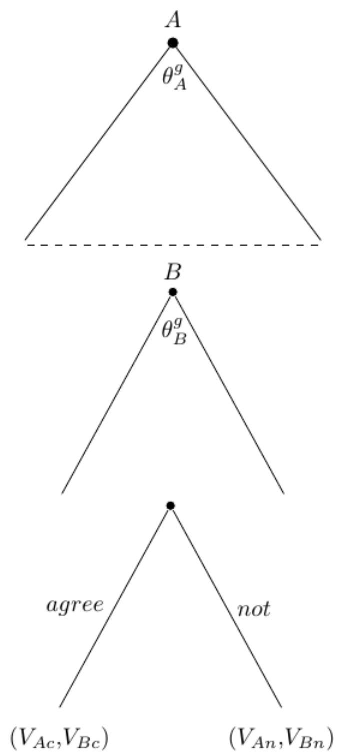

Figure 2: Game Tree of the Election Game

Elections are held simultaneously in both countries. Voters in country A elect governments with type θ_A^g, voters in country B elect governments with type θ_B^g. Governments and voters prefer different quantities for the agreement which are reflected in their specific type parameters. Voters do not know which governments are elected in the respective other country, as they move simultanously. The information set describes the simultaneous moves and shows that the types chosen by the respective other countries are not known when the action of electing a government takes place. We therefore have a simultaneous move game with incomplete information. The governments with the elected types then negotiate abatement quantities on the international level and come to an agreement over quantities or not. If governments come to an agreement, the payoffs are described by (V_{Ac}, V_{Bc}). If they do not come to an agreement, payoffs are determined by the non-cooperative solution found in Section 3.3 above and they receive (V_{An}, V_{Bn}).

3.4.2 Finding the Cooperative Quantities

Since we now know the order of movement in the election game, we can determine the payoffs described in the game tree and subsequently solve the game. Payoffs are determined by the equilibrium quantities of the cooperative scenario, where countries bargain with each other on the international level. The strategy of the respective other country is taken into account when a government proposes a certain quantity x_{ic}. In addition, the choice of the magnitude of the quantity is affected by the government type θ_i^g.

To ensure a fair division of the overall gains of the agreement, transfers are included in the model. The transfers are split equally, such that $T_A = -T_B$. Transfers are added to both the government and voter payoffs.

To solve the game we use the Nash Bargaining Solution. This solves for

$$(x_{Ac}^*, x_{Bc}^*, T_A^*, T_B^*) \in argmax_{x_{Ac}, x_{Ac}, T}(V_{Ac}^g - V_{An}^g)(V_{Bc}^g - V_{Bn}^g).$$

The utility of the difference between the optimal quantity plus the optimal transfer and the default or threat point quantity is maximised for both countries. Gains are split equally between the countries. We first need to determine the equilibrium quantities for the cooperative solution and calculate the corresponding transfers. This allows us to determine the government payoffs. We can then solve for the government types. Cooperative government payoffs are denoted by V_{Ac}^g and V_{Bc}^g respectively and are given by

$$V_{Ac}^g(x_{Ac}, x_{Bc} \mid \theta_A^g) = x_{Ac}^* - \theta_A^g(x_{Ac}^* + s x_{Bc}^*)^2 + T_A^* \tag{8}$$

$$V_{Bc}^g(x_{Ac}, x_{Bc} \mid \theta_B^g) = x_{Bc}^* - \theta_B^g(x_{Bc}^* + s x_{Ac}^*)^2 + T_B^*. \tag{9}$$

To determine x_{Ac}^* and x_{Bc}^* the following aggregate equation is solved for the NBS:

$$V_{Ac}^g + V_{Bc}^g = x_{Ac} - \theta_A^g(x_{Ac} + s x_{Bc})^2 + T_A + x_{Bc} - \theta_B^g(x_{Bc} + s x_{Ac})^2 + T_B.$$

We use the aggregate equations as we want to maximise the product of the payoffs as described above. The gains are then distributed equally. The aggregate payoff is maximised with respect to x_{Ac}, x_{Bc}, T_A and T_B.

The transfers equally distribute the gains from the cooperative solution compared to the non-cooperative payoff between the two countries and are defined by

$$T_i = \frac{1}{2}[(x_{jc} - \theta_j^g D_{jc}) - (x_{ic} - \theta_i^g D_{ic}) + (x_{in} - \theta_i^g D_{in}) - (x_{jn} - \theta_j^g D_{jn})].$$

For the quadratic damage function the individual transfers are given by

$$\begin{aligned} T_A = \frac{1}{2}[&(x_{Bc} - \theta_B^g(x_{Bc} + s x_{Ac})^2) - (x_{Ac} - \theta_A^g(x_{Ac} + s x_{Bc})^2) + \\ &(x_{An} - \theta_A^g(x_{An} + s x_{Bn})^2) - (x_{Bn} - \theta_B^g(x_{Bn} + s x_{An})^2)] \end{aligned} \tag{10}$$

and

$$\begin{aligned} T_B = \frac{1}{2}[&(x_{Ac} - \theta_A^g(x_{Ac} + s x_{Bc})^2) - (x_{Bc} - \theta_B^g(x_{Bc} + s x_{Ac})^2) + \\ &(x_{Bn} - \theta_B^g(x_{Bn} + s x_{An})^2) - (x_{An} - \theta_A^g(x_{An} + s x_{Bn})^2)]. \end{aligned} \tag{11}$$

Before we can calculate the payoffs, we need to determine the optimal equilibrium quantities. To find x^*_{Ac} and x^*_{Bc} we solve for the first order conditions of the payoff functions given above. These are given by

$$\frac{\partial V^g_{Ac}}{\partial x_{Ac}} = -2\theta^g_A(sx_{Bc} + x_{Ac}) - 2s\theta^g_B(sx_{Ac} + x_{Bc}) + 1 = 0$$

$$\frac{\partial V^g_{Bc}}{\partial x_{Bc}} = -2s\theta^g_A(sx_{Bc} + x_{Ac}) - 2\theta^g_B(sx_{Ac} + x_{Bc}) + 1 = 0.$$

To check that the required functional specifications hold, we find the second order conditions

$$\frac{\partial^2 V^g_{ic}}{\partial x^2_{Ac}} = -2\theta^g_{An} - 2s^2\theta^g_{Bn} < 0$$

$$\frac{\partial^2 V^g_{ic}}{\partial x^2_{Bc}} = -2s^2\theta^g_{An} - 2\theta^g_{Bn} < 0.$$

Since the second order conditions are negative for all positive values of s, θ^g_A and θ^g_B, a maximum point of the function exists.

Setting the FOCs equal to zero and solving for x_{Ac} and x_{Bc} gives

$$x^*_{Ac} = \frac{\theta^g_B - s\theta^g_A}{2\theta^g_A\theta^g_B(1-s)(1+s)^2} \tag{12}$$

$$x^*_{Bc} = \frac{\theta^g_A - s\theta^g_B}{2\theta^g_A\theta^g_B(1-s)(1+s)^2}. \tag{13}$$

We can now solve for the transfers, using x^*_{An}, x^*_{Bn}, x^*_{Ac} and x^*_{Bc} determined above and inserting them back into the equations for the transfers given by (10) and (11) above. The transfers therefore equal

$$T^*_A = \frac{1}{8}s^2(s+3)\frac{\theta^g_A - \theta^g_B}{\theta^g_A\theta^g_B(1-s)(1+s)^2} \tag{14}$$

and

$$T^*_B = \frac{1}{8}s^2(s+3)\frac{\theta^g_B - \theta^g_A}{\theta^g_A\theta^g_B(1-s)(1+s)^2}. \tag{15}$$

Taking x^*_{Ac}, x^*_{Bc}, T^*_A and T^*_B from above and inserting them into equations (8) and (9) gives the payoffs of the governments for the cooperative solution including transfers. They are denoted by

$$V^g_{Ac}(x^*_{Ac}, x^*_{Bc} \mid \theta^g_A, \theta^g_B) = \frac{\theta^g_A(s^3+3s^2+4s) - \theta^g_B(s^3+3s^2+2s+2)}{8\theta^g_A\theta^g_B(s^3+s^2-2s-1)}$$

$$V^g_{Bc}(x^*_{Ac}, x^*_{Bc} \mid \theta^g_A, \theta^g_B) = \frac{\theta^g_B(s^3 + 3s^2 + 4s) - \theta^g_A(s^3 + 3s^2 + 2s + 2)}{8\theta^g_A \theta^g_B (s^3 + s^2 - 2s - 1)}.$$

Payoffs for both countries are symmetric. The graph in Figure 3 below shows the distribution of the payoffs for country A. Payoffs for country B are analogous. The graph shows the payoffs when $s = \frac{1}{3}$. We can see that government payoffs for country A decrease as θ^g_A increases. Payoffs also decrease as θ^g_B decreases. Similar results can be observed when we fix $s = \frac{2}{3}$. However, payoffs are lower overall and decrease more quickly for higher values of s, than for lower values of s.

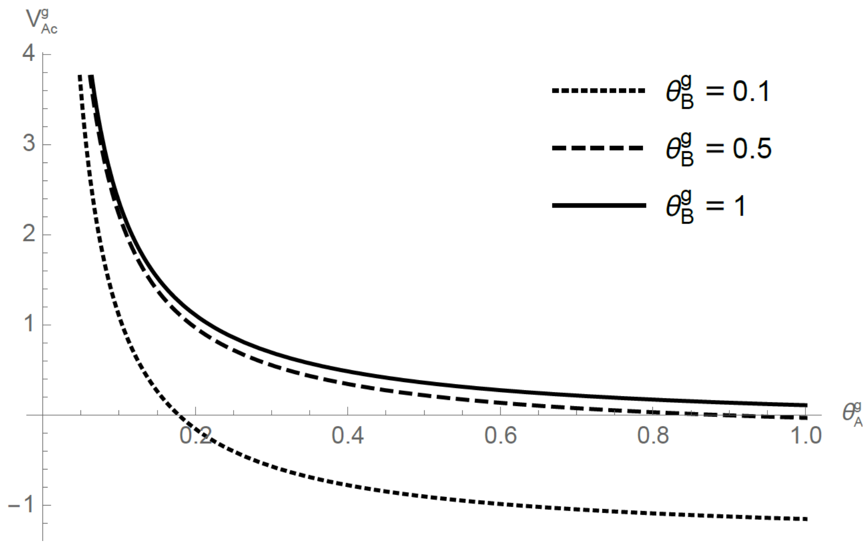

Figure 3: Cooperative Government Payoffs for Country A

When we compare the government payoffs in this section to the non-cooperative results from Section 3.3, we see that payoffs are slightly higher for the cooperative scenario. This persists as s increases. Overall payoffs decline as s increases, but the cooperative solution always gives a higher payoff than the corresponding non-cooperative solution.

In the next subsection, the median voter payoffs will be determined and then compared to the government payoffs.

3.4.3 Determining Types and Payoffs for Governments and Voters

Voters can influence their payoffs by deciding which governments to elect. Governments in this model are elected by majority voting and the elected governments then go on to negotiate over quantities on the international level. The voter payoff is defined by the combination of x^*_{Ac}, x^*_{Bc}, T^*_A and T^*_B the governments agree upon. The voter payoff including side payments using the quadratic specification is given by

$$P^h_{Ac} = x^*_{Ac}(\theta^g_A, \theta^g_B) - \theta^h_A(x^*_{Ac}(\theta^g_A, \theta^g_B) + s x^*_{Bc}(\theta^g_A, \theta^g_B))^2 + T^*_A(\theta^g_A, \theta^g_B) \quad (16)$$

$$P^h_{Bc} = x^*_{Bc}(\theta^g_A, \theta^g_B) - \theta^h_B(x^*_{Bc}(\theta^g_A, \theta^g_B) + sx^*_{Ac}(\theta^g_A, \theta^g_B))^2 + T^*_B(\theta^g_A, \theta^g_B). \tag{17}$$

To determine the payoff of an individual voter, we use the median voter theorem. We are therefore only interested in the median voter's election choice, as the median voter's vote will determine the election in the given majoritarian election system. The median voter's payoff is described by P^h_i, where $i = \{A, B\}$. The voter's preferences are defined by the parameter θ^h_i, which reflects the type of the voter in terms of environmental preferences. Before finding the median voter type and payoffs, we solve for the government types and payoffs, as these determine the voter payoffs.

To find the optimal values of θ^g_A and θ^g_B we solve equations (16) and (17) for the Nash Equilibrium of the game. We first insert the values for x^*_{Ac}, x^*_{Bc}, T^*_A and T^*_B obtained above into equations (16) and (17). Then we can solve for the NE and determine the government types. The first order conditions of the payoff functions are given by

$$\frac{\partial P^h_{Ac}}{\partial \theta^g_A} = \frac{\theta^g_A(s^3 + 3s^2 + 4) + 4\theta^h_A(s-1)}{8\theta^g_A\theta^g_B(s-1)(s+1)^2} = 0$$

$$\frac{\partial P^h_{Bc}}{\partial \theta^g_B} = \frac{\theta^g_B(s^3 + 3s^2 + 4) + 4\theta^h_B(s-1)}{8\theta^g_A\theta^g_B(s-1)(s+1)^2} = 0.$$

The second order conditions are denoted by

$$\frac{\partial^2 P^h_{Ac}}{\partial \theta^{g2}_A} = \frac{-\theta^g_A(s^3 + 3s^2 + 4) - 6\theta^h_A(s-1)}{4\theta^g_A(s-1)(s+1)^2} < 0$$

$$\frac{\partial^2 P^h_{Bc}}{\partial \theta^{g2}_B} = \frac{-\theta^g_B(s^3 + 3s^2 + 4) - 6\theta^h_B(s-1)}{4\theta^g_B(s-1)(s+1)^2} < 0.$$

The second order conditions are negative for all positive values of θ^g_A and θ^g_B, therefore a maximum point of the function exists.

Setting the first order conditions equal to 0 and solving for θ^g_A and θ^g_B gives

$$\theta^{g\,*}_A = \frac{4\theta^h_A(1-s)}{s^3 + 3s^2 + 4} \tag{18}$$

$$\theta^{g\,*}_B = \frac{4\theta^h_B(1-s)}{s^3 + 3s^2 + 4}. \tag{19}$$

To find the voter payoffs we now substitute x^*_{An}, x^*_{Bn}, x^*_{Ac} and x^*_{Bc} derived above into the voter payoff functions given by equations (16) and (17) above. This gives

$$P^h_{Ac} = \frac{-2\theta^h_A\theta^g_B(s-1) + \theta^g_A s(4 + 3s + s^2) - \theta^g_A\theta^g_B(4 + 3s^2 + s^3)}{8(\theta^g_A)^2\theta^g_B(s-1)(1+s)^2} \tag{20}$$

$$P^h_{Bc} = \frac{s(\theta^g_B)^2(4 + 3s + s^2) - \theta^g_A(\theta^g_B(4 + 3s^2 + s^3) + 2\theta^h_B(s-1))}{8(\theta^g_B)^2\theta^g_A(s-1)(1+s)^2}. \tag{21}$$

Substituting ${\theta_A^g}^*$ and ${\theta_B^g}^*$ into equations (20) and (21) above gives the cooperative voter payoffs in country A and B for the optimal government types found in equations (18) and (19). The payoffs are

$$P_{Ac}^h = -\frac{(4+3s^2+s^3)(2s\theta_A^h(4+3s+s^2) - \theta_B^h(4+3s^2+s^3))}{64\theta_A^h\theta_B^h(s^2-1)^2} \tag{22}$$

$$P_{Bc}^h = \frac{(4+3s^2+s^3)(\theta_A^h(4+3s^2+s^3) - 2s\theta_B^h(4+3s+s^2))}{64\theta_A^h\theta_B^h(s^2-1)^2}. \tag{23}$$

Next we want to find the median voter type to determine the individual voter payoff. The median voter is important, as the median voter's vote will determine the election and therefore define which government type is elected into office. The parameter θ^h which defines the voter type is chosen from a uniform distribution where $\theta \sim U[0,1]$. The median voter's type θ^m is found by ranking all voters according to their preference parameter and choosing the median. Since this is a uniform distribution, the median voter type θ^m will equal $\frac{1}{2}$. As both countries have the same distributional specification for θ^h, the median voter's type is given by

$$\theta_A^m = \theta_B^m = \frac{1}{2}.$$

The voter payoffs with the median voter type are then given by

$$P_{Ac}^h = \frac{-(4+3s^2+s^3)(-4+8s+3s^2+s^3)}{32(s^2-1)^2}$$

$$P_{Bc}^h = \frac{-(4+3s^2+s^3)(-4+8s+3s^2+s^3)}{32(s^2-1)^2}.$$

Voter payoffs in country A and B are symmetric. The graph in Figure 4 below shows the results for country A when $s = \frac{1}{3}$. Results for country B are analogous. We can see that the voter payoffs in country A decrease as θ_A^h increases. This result is the same for voter and government payoffs. When the value of s increases, payoffs for voters decrease, as was also the case for the government payoffs. When s gets too large, payoffs even become negative. This behaviour is easily explained when we remember that the parameter s stands for the spillover effect. If the spillover is high, country B free rides on country A. Country A therefore has to shoulder most of the burden and has higher costs, while country B benefits. It therefore makes sense, that low values of s give a higher payoff than high values of s. In general, payoffs decrease as θ^h increases, as a higher θ means that the effects of pollution are felt more strongly. Payoffs are therefore lower if pollution is seen as more dangerous, or has a greater effect on the country and its citizens.

The voter payoffs for the election game when we asume that $\theta_A^h = \theta_B^h$ are described in Figure 5 below. This graph shows the voter payoffs graphed against the voter type, for four specific chosen values of s. We can see that there is a cut-off value for s, when the

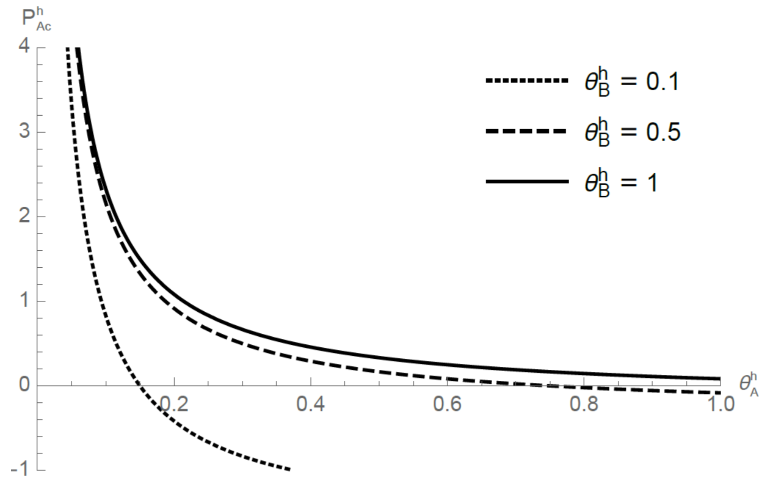

Figure 4: Cooperative Payoffs for Voters in Country A with $s = \frac{1}{3}$

payoffs become negative. Up to this point, voter payoffs decrease as the type parameter increases. This is consistent with the analysis from the sections above, as a higher θ means that voters are affected more by the environmental degradation, so their payoffs are more strongly reduced. When s becomes too large, the voter payoffs become negative. A high s is therefore not desirable. However, as s is an exogenous parameter, the players in the games cannot influence its value.

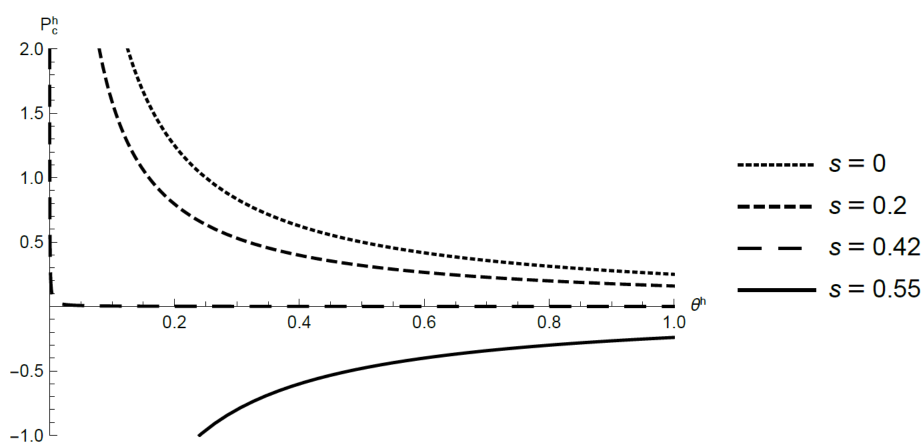

Figure 5: Voter Payoffs for Equal Types in Both Countries

3.5 The Ratification Game

In the ratification game model the order of movement is changed compared to the election game model. Governments in the two countries are given in the first stage of the game. This can be understood as incumbent politicians negotiating an agreement that was not directly influenced by the results of an election. Governments can have any type specified by the uniform distribution $\theta_i^g \sim U[0,1]$. The governments again bargain over quantities in the international setting, but this time the bargaining stage is the first stage of the game, followed by a ratification stage at the end of the game.

The quantities the governments agree upon in the international negotiation stage must be ratified by the voters in the individual home countries. Governments anticipate the voters' ratification choices when bargaining over quantities. As governments choose quantities simultaneously, we again have a simultaneous move game of incomplete information, as in the election game described above. The ratification of the IEA by the voters in both countries in the last stage of the game also occurs simultaneously.

The ratification game is described in the game tree in Figure 6 below. Governments in country A and B move simultaneously and choose their preferred quantities. The countries do not know the chosen quantities of the respective other country. This is described by the information sets. After the countries have chosen their abatement quantities, these quantities must be ratified by the voters at home. Voters in country A and B move simultaneoulsy and decide between ratifying the agreement or not ratifying the agreement. If both countries ratify, the government payoffs are given by the cooperative payoffs (V_{Ac}, V_{Bc}). If one or both countries do not ratify, the payoffs are given by the non-cooperative payoffs (V_{An}, V_{Bn}).

Voters will only ratify the agreement if the negotiated quantities of the agreement lead to a higher payoff than the default payoff with the non-cooperative quantities without an agreement. The agreement must be ratified in both countries to become binding and will enter into force if

$$P_{Ac}^h > P_{An}^h \cap P_{Bc}^h > P_{Bn}^h.$$

To determine the quantities and types for which the agreement is ratified, we compare the outcomes of the cooperative and non-cooperative payoffs and determine the values for which the payoffs are maximised. The voter payoffs for the non-cooperative solution are given by

$$P_{An}^h(x_{An}, x_{Bn} \mid \theta_A^h) = x_{An}(\theta_A^h) - \theta_A^h(x_{An}(\theta_A^h) + sx_{Bn}(\theta_A^h))^2$$

$$P_{Bn}^h(x_{An}, x_{Bn} \mid \theta_B^h) = x_{Bn}(\theta_B^h) - \theta_B^h(x_{Bn}(\theta_B^h) + sx_{An}(\theta_B^h))^2.$$

Since the threat point is the same for the election game and the ratification game, we can use the non-cooperative values obtained in Section 3.3 above to calculate the non-cooperative voter payoffs in the ratification game. Using the results for x_{An} and x_{Bn} obtained in equations

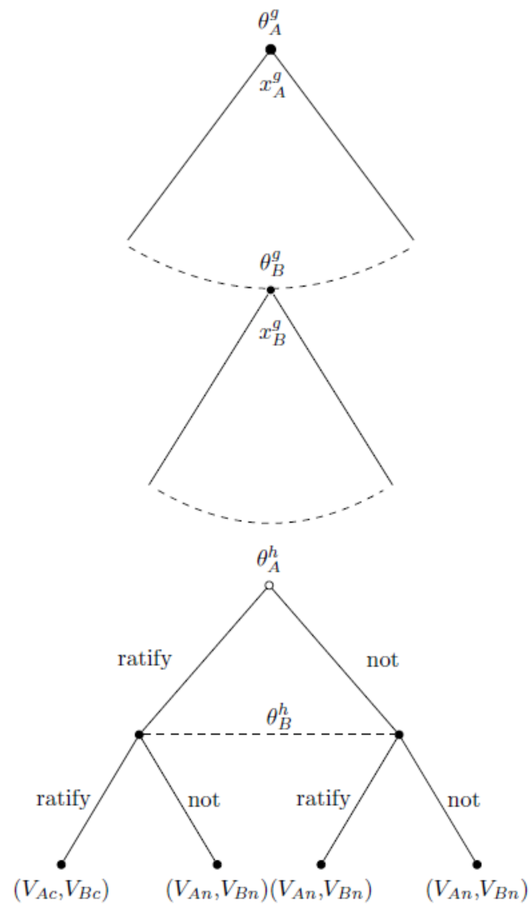

Figure 6: Game Tree of the Ratification Game

(4) and (5) above, the payoffs for the non-cooperative solution are given by

$$P_{An}^h(x_{An}, x_{Bn} \mid \theta_A^h) = \frac{\theta_B^h(s^2+1) - 2s\theta_A^h}{4\theta_A^h\theta_B^h(1-s^2)} \tag{24}$$

$$P_{Bn}^h(x_{An}, x_{Bn} \mid \theta_B^h) = \frac{\theta_A^h(s^2+1) - 2s\theta_B^h}{4\theta_A^h\theta_B^h(1-s^2)}. \tag{25}$$

The voter payoffs with the negotiated quantities must be higher than the payoffs given in equations (24) and (25) above for the agreement to be ratified.

The voter payoffs for the cooperative solution are defined by

$$P_{Ac}^h(x_{Ac}, x_{Bc} \mid \theta_A^h) = x_{Ac}(\theta^g) - \theta_A^h(x_{Ac}(\theta^g) + sx_{Bc}(\theta^g))^2 + T_A \tag{26}$$

$$P_{Bc}^h(x_{Ac}, x_{Bc} \mid \theta_B^h) = x_{Bc}(\theta^g) - \theta_B^h(x_{Bc}(\theta^g) + sx_{Ac}(\theta^g))^2 + T_B \tag{27}$$

where T_A and T_B are defined as follows

$$T_A = \frac{1}{8}s^2(s+3)\frac{\theta_A^g - \theta_B^g}{\theta_A^g\theta_B^g(1-s)(1+s)^2}$$

$$T_B = \frac{1}{8}s^2(s+3)\frac{\theta_B^g - \theta_A^g}{\theta_A^g\theta_B^g(1-s)(1+s)^2}.$$

The transfers are therefore given as in the election game and depend on the government types. We want to determine if the cooperative or the non-cooperative setting in the ratification game is more benefitial to the voters and to what extent voters can influence the outcome with their choices. Since voters ratify the IEA in the last stage of the game, they always have the option of rejecting the agreement and obtaining the non-cooperative payoffs. The cooperative voter payoffs must therefore be higher than the non-cooperative voter payoffs for the IEA to enter into force. Governments know that this is the case and will adapt their negotiations accordingly, by taking the voters' type and corresponding action into account.

The government payoffs depend on the ratification decision of the voters. If the voters do not ratify the agreement, then the government payoffs will be V_{An}^g and V_{Bn}^g respectively. These non-cooperative payoffs are given by equations (6) and (7) above. If the voters ratify the agreement, governments will get V_{Ac}^g and V_{Bc}^g respectively as payoffs. These payoffs include transfers and are given as in the election game in Section 3.4. above. The complete problem which includes the cooperative and non-cooperative payoffs is summarised by the functions below for the general case

$$V_A^g(x_{Ac}, x_{Bc}) = \begin{cases} x_{Ac} - \theta_A^g(x_{Ac} + sx_{Bc})^2 + T_A & P_{Ac}^h \geq P_{An}^h \cap P_{Bc}^h \geq P_{Bn}^h \\ x_{An} - \theta_A^g(x_{An} + sx_{Bn})^2 & P_{Ac}^h < P_{An}^h \cup P_{Bc}^h < P_{Bn}^h \end{cases} \tag{28}$$

$$V_B^g(x_{Ac}, x_{Bc}) = \begin{cases} x_{Bc} - \theta_B^g(x_{Bc} + sx_{Ac})^2 + T_B & P_{Ac}^h \geq P_{An}^h \cap P_{Bc}^h \geq P_{Bn}^h \\ x_{Bn} - \theta_B^g(x_{Bn} + sx_{An})^2 & P_{Ac}^h < P_{An}^h \cup P_{Bc}^h < P_{Bn}^h. \end{cases} \tag{29}$$

To solve the model, we will consider one specific case where we assume that $\theta_A^g = \theta_B^g$ and $\theta_A^h = \theta_B^h$. This means that we assume that countries are completely symmetric regarding voter and government preferences. They will prefer the same abatement levels and thus there will be no transfers, as no redistribution is necessary. With the above assumptions on the parameters, the government payoffs simplify to one payoff function with symmetric preferences for both countries given by

$$V^g(x_c(\theta^g) \mid x_n(\theta^h)) = \begin{cases} x_c(\theta^g) - \theta^g(x_c(\theta^g) + sx_c(\theta^g))^2 & P_c^h \geq P_n^h \\ x_n(\theta^h) - \theta^g(x_n(\theta^h) + sx_n(\theta^h))^2 & P_c^h < P_n^h. \end{cases} \tag{30}$$

To find the values for which the ratification constraint holds, we evaluate $P_c^h \geq P_n^h$. This holds for

$$x_c(\theta^g) - \theta^h(x_c(\theta^g) + sx_c(\theta^g))^2 \geq x_n(\theta^h) - \theta^h(x_n(\theta^h) + sx_n(\theta^h))^2.$$

Simplifying the inequality shows that the ratification constraint holds for values where

$$x_c(\theta^g) \geq x_n(\theta^h)$$

which follows from the fact that P_c^h is decreasing in x_c. Voters will therefore only ratify an agreement where the proposed government quantities are higher than the non-cooperative default quantities.

To find the optimal solution for the governments, we maximise

$$V_c^g = x_c - \theta^h(x_c(1+s))^2 \tag{31}$$

subject to the ratification constraint defined by $x_c \geq x_n$. To find the solution to the maximisation problem, we initially ignore the ratification constraint. Then we check that the ratification constraint holds for the given solution. Maximising equation (31) gives the following first order condition

$$\frac{\partial V_c^g}{\partial x_c} = 1 - 2\theta^g(1+s)(x_c + sx_c) = 0.$$

Solving the first order condition for x_c gives the optimal cooperative quantity for the governments when ignoring the constraint. This is given by

$$x_c = \frac{1}{\theta^g(1+s)^2}.$$

By substituting equal types into equations (4) and (5) above, we find that

$$x_n = \frac{1}{2\theta^h(1+s)}.$$

We can now check that the ratification constraint holds for the value of x_c given above, by inserting this solution and the known value for x_n into the inequality for the ratification constraint. As long as the constraint holds, the IEA will be ratified. If it does not hold, the IEA is not ratified and the default setting is chosen. The calculations show that the quantities chosen by governments are given by the minimum function

$$x_c = \min\left(\frac{1}{2\theta^g(1+s)^2}, \frac{1}{2\theta^h(1+s)}\right).$$

Voters will therefore ratify any agreement where the quantities proposed by the governments are higher than the non-cooperative quantities given by the default setting. If the quantities proposed by governments are lower than the non-cooperative levels, the voters will reject the agreement and choose the non-cooperative levels instead.

The voter payoffs are found by inserting the chosen quantities into the payoff functions given in equations (24)-(27) above. Since there are no transfers for the symmetric case, the payoff functions are the same for the cooperative and non-cooperative scenario and only differ regarding the chosen quantity. Inserting x_n into the voter payoff function gives a voter payoff of

$$P_n^h = \frac{1+4s-s^2}{4\theta^h(1+s)^2}. \tag{32}$$

We can see that payoffs decrease as the spillover parameter s increases, and increase as it decreases. Higher values of θ^h lead to lower payoffs. This is consistent with the previous model, where both a higher θ^h or higher θ^g also gave a lower overall payoff.

Inserting the chosen government quantity x_c gives a cooperative voter payoff of

$$P_c^h = \frac{2\theta^g - \theta^h}{4(\theta^g)^2(1+s)^2}. \tag{33}$$

Equation (33) therefore describes the payoffs of the voters when the constraint is ratified. The payoffs now depend on both the voter and government types. Payoffs are higher if government and voter types are lower, which is again consistent with previous results. Payoffs are also higher with lower values of s. The graph in Figure (7) below shows the comparison of the voter payoffs. The values for θ^g are taken from the results shown in equations (18) and (19) above, when we assume that both government types are equal. These values for θ^g were chosen as the different models will be compared to each other in the next chapter.

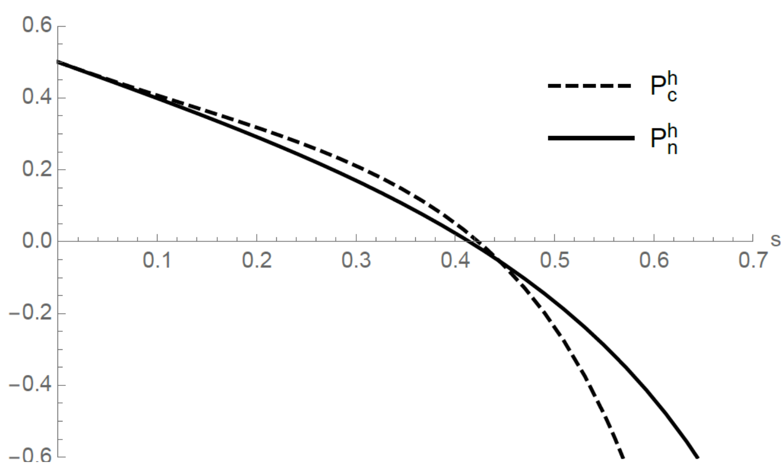

Figure 7: Comparisons of Voter Payoffs in the Ratification Game

The graph clearly indicates up to which point the cooperative payoffs are higher than the non-cooperative payoffs in the ratification game. The graph also shows that payoffs for both functions decrease as s increases. These are not the final results for the ratification game however, as the final payoff also depends on the ratification decision of the voters. Payoffs are only ratified if $P_n^h < P_c^h$.

4 Comparing the Different Scenarios

This section will compare the results of the games described above and answer the question of which setting is most beneficial for governments and voters in terms of payoffs. It will also answer to what extent voters can affect the outcome of the agreements by moving earlier or later in the game. Results are compared to the paper by Buchholz et. al. (2005).

In this paper, three different games were presented. The non-cooperative game does not include international bargaining and can be compared to the "isolationist" situation in the paper by Buchholz et. al. (2005). The election game is also taken from the same paper and reproduced for a specific damage function, to allow for the comparison of magnitudes. The election game includes an international bargaining setting and allows for bargaining between countries. Voters in the countries elect their preferred governments to negotiate. The third model is the ratification game which also includes an international bargaining situation, but differs to the election game as a ratification phase is introduced at the end of the game. The aim is to compare if voters are better off in terms of payoffs in the game without international bargaining, in the game where they elect their governments in the first stage of the game, or in the game where they do not elect governments but can ratify the final agreement.

Buchholz et. al. (2005) find that including voters in the analysis of international environmental bargaining shifts the prisoner's dilemma situation from the governments to the voters. Voters may be worse off in a situation where they elect governments compared to a situation without governments. This also depends on the spillover parameter s. Buchholz et. al. (2005) explain this by voters having an incentive to elect governments that advocate lower abatement quantities than they themselves would prefer, to give their country an advantage in the international negotiation process. Voters may therefore be worse off in a situation where they elect governments, compared to a situation where they do not elect governments, because they do not vote for their true preferences. In the non-cooperative situation the governments simply choose their preferred quantities without negotiating on the international level and voters have a higher incentive to vote for their true preferences, which means that their payoffs will be higher.

The voter and government types define the payoffs of the games. The closer the government and voter types lie to each other, the better. Additionally, the closer the two country types are to each other, the more likely an interior solution becomes. Buchholz et. al. (2005) state that large differences between countries lead to corner solutions. This is simply explained by free riding. If there are large differences between countries and one country decides to offer high abatement quantities, the second country will even benefit with a proposed abatement quantity of zero, as overall gains are divided equally between the two countries. This is true because x_A and x_B are strategic substitutes. The ratification game was solved for the situation where countries are symmetric, as this scenario most clearly shows the effects of differences between voter and government types.

Since the ratification game was solved for the case where $\theta_A^h = \theta_B^h$ and $\theta_A^g = \theta_B^g$, the comparison between the ratification game, election game and non-cooperative setting will also be based on this assumption. From solving the election game for the cooperative situation we know that $\theta^m = \frac{1}{2}$. The corresponding government types are given by equations (18) and (19) above. When taking these values to solve for the voter payoffs in the ratification game given in equation (30) above, we find that the payoffs for the cooperative situation in the election game and the ratification game are exactly the same for all values of $s \in (0, 1)$. Introducing the ratification game stage and letting the voters move later in the game therefore does not affect the payoff function. This is explained by the fact that governments anticipate voter behaviour.

However, the ratification game differs to the election game as the voters decide between the default quantity and the quantity proposed by the governments during the negotiations. Governments will not propose quantities that lead to a lower payoff than the non-cooperative quantities, as this would not be ratified. In this sense the voters have a better position in the ratification game, as they have a fixed lower bound to their payoffs. In the election game it is possible that payoffs for voters are lower than in the non-cooperative case, if they elect governments that are less tough on pollution to give their country a better bargaining position. This is in line with the results of Buchholz et. al. (2005) who state that governments that negotiate are not necessarily greener than isolationist governments, and in both models the governments negotiating are less green than the median voter in the country. In the ratification game, it is guaranteed that the voter payoff will not be lower than the non-cooperative payoff, as quantities that lead to such a result would not be ratified by the voters in the ratification stage of the game.

Buchholz et. al. (2005) argue that governments will choose lower abatement quantities than voters would prefer in any constellation. Even in the isolationist scenario, voters would prefer higher abatement quantities than those chosen by governments. Buchholz et. al. also found that the isolationist situation will likely lead to higher reductions of pollution overall.

Unfortunately, even the ratification process implemented in the ratification game in Section 3.5 cannot ensure that the quantities desired by voters are implemented. Governments anticipate voter behaviour and already choose quantities during the negotiation such that their own payoffs are maximised subject to the ratification constraint defined by the voters. The proposed quantities for the IEA therefore depend crucially on the threat point of the game, as this is the default option, should the ratification fail. However, the threat point also ensures that voters are never worse off than in the non-cooperative situation. In the election game, it is possible that voters are worse off than in the non-cooperative situation. This depends on s. In the ratification game, voters are never worse off than in the non-cooperative situation. The exact payoff again depends on s. This means that voters are better off in the ratification game, as they have a fixed lower bound for the payoffs, while this does not exist in the election game.

Across all scenarios and all games we see that payoffs are higher when the exogenous parameter s, which reflects the spillover effect, is lower. This is easily explained by the free riding phenomenon. Since the parameter s is part of the damage function, the spillover will always be negative, as the damage function reduces overall payoffs. If there is a high spillover effect, then country A's payoffs will be reduced, even if country A takes action to combat pollution. This is especially true, if country A additionally has a value of θ that lies closer to 1, as $s = 1$ reflects a complete spillover effect.

The parameter s is exogenous and cannot be affected by country A's choice of action. Country A therefore receives a higher payoff with a low s, as less spillover means that country A's actions are more directly reflected in the payoffs country A receives. If s is high, even if country A takes action to increase its payoffs further, this would only lead country B to reduces its contributions and free ride on country A. Country A therefore cannot benefit from a high spillover effect. The argumentation is analogous for the payoffs of country B.

5 Conclusion

This thesis presented three different models for the negotiation of an IEA. The models differ with regard to the order of movement of governments and voters and the existence of an international negotiation stage or not. All scenarios have decreasing payoff functions, where lower values of θ give higher values of voter payoffs, P^h. This is due to the definition of the type, where a higher type value reduces the payoffs. Payoffs decrease as your own country's voter or government types increase, and increase as the types of the other country decreases. Payoffs in all models also decrease when the spillover parameter s increases. Both of these results are due to free riding.

The election game originally presented in Buchholz et. al. (2005) was reproduced with a specific quadratic function and the results compared to a new model, called the ratification game, where voters move later in the game. The aim was to determine if voter payoffs could be improved in the second game. The ratification game was solved for the case where voters in both countries and governments in both countries have equal types. This was done to focus on the effect of the differences in types and to ensure an interior solution, as large differences between countries lead to corner solutions. The results show that assuming equal voter types and equal government types leads to equal payoff functions for the election and ratification game. However, since voters decide between implementing the quantities from the bargaining process if they accept the agreement and quantities from the non-cooperative situation if they reject the agreement, the have a better position in the ratification game, as they can never be worse off than in the non-cooperative situation. Since Buchholz et. al. (2005) showed that the cooperative situation in the election game may lead to worse payoffs for the voters than quantities from the non-cooperative game, the implementation of a ratification stage benefits the voters.

This thesis found that changing the order of movement between voters and governments improves voter payoffs, as the non-cooperative threat point ensures that they receive a higher payoff than for some values of s in the election game. Further research could include solving the ratification game model for the general case, where differences between types are possible. It could also be interesting to look at other ways of increasing the bargaining power of voters, so that their preferred levels of abatement are better reflected in the international negotiations. In the games presented above, quantities reflect government preferences more than they reflect voter preferences. Further extension to the model may allow payoffs to lie closer to voter preferences than government preferences.

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7 Appendix

Abstract

This thesis compares different models of international environmental negotiations and solves these models using the Nash Bargaining Solution. The aim is to show the influence of voters in an international bargaining setting and to improve their payoffs. Voters can either elect governments in the first stage of the game or ratify the international agreement in the last stage of the game. Both of these situations are compared to the non-cooperative threat point. Results show that governments propose lower abatement quantities than voters would prefer in any situation, but voters are slightly better off in the ratification game as they are never worse off than in the non-cooperative situation.

Zusammenfassung

Diese Arbeit vergleicht verschiedene internationale Klimaverhandlungsmodelle, welche mit der Nash Bargaining Methodik gelöst werden. Ziel der Arbeit ist es, den Einfluss der Wähler auf internationale Klimaverhandlungsprozesse zu bestimmen und ihren Nutzen zu maximieren. Wähler können entweder im ersten Schritt die Regierungen wählen, oder im letzten Schritt die Vereinbarung ratifizieren oder ablehnen. Diese beiden Modelle werden mit der nichtkooperativen Situation verglichen. Die Ergebnisse zeigen, dass Regierungen in allen Situationen niedrigere Reduzierungsmengen vorschlagen, als Wähler bevorzugen würden. Wähler sind jedoch im Ratifizierungsspiel etwas besser gestellt, da sie nie schlechter gestellt sind als in der nichtkooperativen Situation.