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AVOIDING THE TRAGEDY OF THE COMMONS

Transferring Ostrom's Design Principles to Global Climate Change Mitigation by Preservation of the Atmosphere

Climate change is one of the most important issues facing the international community at present. Traditional collective action, as illustrated by the "Tragedy of the Commons" does not provide much hope for the preservation of the global commons, such as our atmosphere. There are however many examples of sustainable management systems for local environmental common-pool resources. The 2009 Nobel Laureate, Elinor Ostrom, has presented a framework of eight design principles that characterize such systems (1990). In this thesis we analyze the transferability of her framework to global climate change mitigation by preservation the atmosphere. Using a wide range of economic theory, but with an emphasis on collective action theory and game theory, we show that most of Ostrom's design principles are indeed transferable to varying extents. Analyzing the transferability of the framework also provides valuable insights on important elements and procedures in how to manage a global system for the preservation of the atmosphere.

keywords: *common-pool resource; collective action; climate change; emissions reduction; Tragedy of the Commons*

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1. Introduction

One of the most pressing challenges facing the international community at present is the issue of anthropogenic[1] climate change, caused by the already elevated and continuously increasing concentration of greenhouse gases (henceforth GHG) in the atmosphere. Traditional collective action theory in the style of Olson (1965) and Hardin (1968) does not provide much hope for a solution to the issue. There are however many examples of sustainable management systems for local environmental commons. Scholarly work undertaken by Prof. Elinor Ostrom, the 2009 Nobel Laureate in Economics, has identified several characteristics that these systems have in common.[2] This thesis will analyze the transferability of the framework presented in Ostrom's *Governing the Commons: The Evolution of Institutions for Collective Action* (1990) to global scale climate change mitigation through preservation of the atmosphere. It will be shown that though not all of Ostrom's design principles are transferable, they provide valuable insights on how to manage a global system of GHG emissions reduction.

According to the influential Stern Review "*international* collective action will be critical in driving an effective, efficient and equitable response on the scale required" (Stern, N., 2006, p. i, emphasis added). The international track record, as represented by efforts such as the Kyoto Protocol and the Copenhagen Summit, has however given an insufficient and disturbingly innocuous approach to tackling the problem. The major query seems to derive from the difficulty in achieving cooperation among nations and in presenting a united front of collective action.

An approach for successful collective action, albeit on a smaller scale, that has received multiple acclaim recently is that of Ostrom. She maintains that "empirical and theoretical research --- over the past 30 years --- has shown that tragedies of the commons are real, but not inevitable" (Ostrom, E., et al., 1999, p. 281). In *Governing the Commons* (1990), Ostrom presents a framework of eight design principles characterizing communities that successfully manage to preserve common-pool resources (henceforth CPRs) through collective action.

The question arises of how to develop an international framework governing the successful collective action in mitigating climate change? A useful approach is to investigate to what extent Ostrom's (1990) eight design principles can be applied on a global scale. The question is particularly interesting because of the inherent general similarities in characteristics found between the common resources at a local level and at the global level (the atmosphere).

[1] Anthropogenic = caused by human activity.
[2] Elinor Ostrom is Arthur F. Bentley Professor of Political Science at Indiana University, in Bloomington, IN, USA.

This enables drawing wisdom from successful local collective action for global advancement within the field. Secondly, setting the atmosphere as the target for preservation and using Ostrom's design principles of CPR conservation enables a further exploration of how to effectively establish sustained international cooperation on this issue. Essentially it provides an understanding of driving mechanisms within an international governance system, thus paving the road for successful cooperation regarding GHG emissions reductions in the future.

1.1. Aim

To acquire insight on how to achieve a global system for climate change mitigation through preservation of the atmosphere, by analyzing Ostrom's work on CPRs using relevant economic theory, in particular research on collective action and game theory.

1.2. Research Questions

To what extent can Ostrom's (1990) design principles on the successful management of local environmental CPRs be transferred to a global system for the preservation of the atmosphere? What insights can be drawn?

1.3. Previous study within this field

For this thesis there are two primary fields of scholarly material to consider; on the one hand there is the literature on CPRs and on the other the literature on the economics of climate change. Many studies and solutions have been presented on the small to medium scale mobilization of collective action to preserve CPRs,[3] though there are unfortunately few summary publications. Martin (1989) compiled the empirics of many cases from varying academic disciplines, while Ostrom's summary of the literature in *Governing the Commons* (1990) remains one of the best overviews. Extensive studies taking wisdom from successful collective action at a smaller scale and applying it to the international community have, to our knowledge, not been explicitly made. Given the acceptance that Ostrom's (1990) framework has in the academic community and given the similarities between local and global CPRs, we see a need and an opportunity to investigate whether Ostrom's eight design principles are transferable to the global level and climate change mitigation in particular.

One of the first economic studies on the effects of climate change and possible ways to address it was made by Nordhaus (1994). As the understanding of the scientific mechanisms driving climate change has deepend, there have in the last decade been many studies on the costs of the consequences of climate change, as well as on the costs and mechanisms to mitigate it.

[3] Some examples include Agrawal, A., & Goyal, S., 2000; Schlager, E., 1994; Schlager, E., Blomquist, W., & Tang, S. Y., 1994; Ostrom, E., Gardner, R., & Walker, J., (1994); Dietz, T., Ostrom, E., & Stern, P., 2003; Blomquist, W., 1992.

This field is unfortunately too extensive to describe in detail here. The most important of the reviews of the economic effects of climate change is the Stern Review, published in 2006.[4] The Stern Review has however received criticism, in particular for the very low rate of utility discounting used to support the analysis (Weitzman, M., 2007; Beckerman, W., & Hepburn, C., 2007).[5] Nevertheless, since the Stern Review is one of the most widely influential studies in cost-benefit analysis of climate change available at the moment, its conclusions will be used as guidelines for characterizing the consequences of climate change.

It appears to be a widely held notion that any action targeting climate change must be globally coordinated. It has however been disputed whether a solution on a global scale is needed or even possible, and that the focus should be on issues of adaptation rather than on striving for an all-encompassing global solution to reduce GHG emissions (Bierbaum, R., 2008). Nonetheless, it has also been maintained that a solution to the problem of global warming and preservation of the atmosphere requires an adaptation of global institutions (Ostrom, E., 2009).

1.4. Method

The conduct of this paper is essentially to apply a theoretical framework developed for a local environment to a global context. Potential factors of success as well as failure that could arise when considering the applicability of Ostrom's theory to an international framework of cooperation regarding climate change will be discussed. Ostrom's eight principles of collective action will at first be discussed separately. Initially a careful consideration of the implications of each principle will be presented. Secondly an attempt will be made at testing these implications using relevant game theoretic tools and/or a broader microeconomic perspective. Finally, consideration is given to the factors inherent to the success or failure of transferring the principles to a global scale. The analysis will be kept at a theoretic level to the extent possible. However, empirical characteristics of the problem will be used when these significantly impact the theoretical framework. Finally, a concluding discussion will be presented considering the transferability of the principles to an international system of governance.

Great care is taken that the theoretical framework of the paper be built on sources having acquired general recognition and acceptance within the academic community. Other sources are considered for the knowledge and objectivity they present as well as the insights they can give on the issue. Credibility is a major aim of this text and particular attention has been given to the choice of references and sources. This is essential due to the wide array and substantial number

[4] 'Stern Review' is the informal name for Stern, N., (2006) *The Stern Review on the Economics of Climate Change*, UK Treasury. We will use the informal name or (Stern, N., 2006) to refer to this document throughout the thesis.
[5] Instead of stating that the discounting rate is wrong researchers claim that it is far less obvious what exact rate of interest should be used.

of theories that will be presented throughout the paper. Focus on quality and range of theoretical material is important in being able to draw truly valuable insights.

Research within the field of environmental economics essentially requires both normative and positive analysis. Positive analysis supplies the tools for understanding the interaction between economics, politics and the environment. A normative analysis on the other hand gives us the grammar of policy arguments i.e. the logic of arguments used in trying to argue a certain case. The primary objective of this paper is thus on a normative level. Nevertheless, the positive analysis is irrefutable to the subject and is essential for an underlying understanding of the question.

1.5. Limitations

It is not the purpose of this paper to challenge the principles already set up by Ostrom (1990). It is therefore important to distinguish between the relevant underlying mechanisms driving collective action at the local and global level. The discussion, furthermore, centers on the collective action taking place on an international level *between* nation states. The assumption is therefore made that governments are perfectly able to carry out the reductions of GHG emissions. Potential deviations from the intended policy outcome caused by agency problems, similar to those described by Jensen and Meckling (1976), are therefore excluded. [6]

Finally, it is important to note that even with these limitations it is difficult, if not impossible, to present an all-encompassing study featuring all the factors governing global collective action. It is therefore important to emphasize the fact that the aim of this study is to only present some considerations in the organization of this wide-ranging undertaking and yield to the fact that a universally valid conclusion cannot be made.

2. Background

The certainty with which it can be established that rising levels of GHGs in the atmosphere are a result of human activity was in 2007 estimated to 90% (IPCC, 2007). Carbon dioxide (CO_2) is the most important GHG in view of the immense volumes that are emitted. Although the Earth reabsorbs much CO_2 through natural processes such as photosynthesis, human activity releases approximately twice as much CO_2 into the atmosphere than is reabsorbed (Stern, N., 2006). Currently the stock of GHGs in the atmosphere is 430 parts per million (ppm) CO_2e.[7] The concentration was only 280 ppm before the Industrial Revolution and, cetris paribus, it could

[6] Agency problems happen when the agent has different incentive structures than the principal, on whose behalf the agent acts.
[7] CO_2e is the abbreviation of 'carbon dioxide equivalent'; GHGs other than CO_2 are converted into CO_2 according to the strength of their GHGs properties.

reach 550 ppm CO_2e by 2050. If this were the case, a global average temperature rise of more than 2°C would be highly likely. However, due to the accelerating rate of GHG emissions into the atmosphere this concentration could already be reached by the year 2035 (Stern, N., 2006).

Although there is no definitive answer to what the implications of climate change would be, the consequences of a 2ºC increase in global temperature are likely to be wide-spread and severe. "Climate change threatens the basic elements of life for people around the world – access to water, food production, health, and use of land and the environment" (Stern, N., 2006, p. vi). Ultimately, costs associated with a 2-3°C increase in global average temperature will likely result in a 0-3% permanent loss of global output. Over the next century it is likely that there will be a 5-6°C rise in temperature which in turn might cause an estimated 5-10% loss of global GDP. For both of these scenarios, developing countries will be suffering a higher portion of the loss (Stern, N., 2006). [8]

According to the Stern Review, in order to stabilize atmospheric GHG concentrations at or below 550 CO_2e, global emission in 2050 have to be approximately 25% below current levels. Cutting global GHG emissions to this extent would entail significant costs which the Stern Review estimates to be at approximately 1 % of GDP on average by 2050.

There have to date been three major global accords for the preservation of the atmosphere in order to reduce climate change; the United Nations Framework Convention on Climate Change (UNFCCC, 1992)[9], the Kyoto Protocol to the UNFCCC (1997) and the Copenhagen Accord (2009) There are several NGOs as well as UN organs such as Greenpeace, the WWF, the United Nations Environment Programme (UNEP) and the Intergovernmental Panel on Climate Change (IPCC) that work with the issue on a global level.

The Kyoto Protocol specified that developed countries, so called Annex 1 countries, should limit their GHG emissions by on average 5.2% below 1990 levels during the period 2008-12. No such targets were set for developing countries.[10] After a slow ratification process, the Kyoto Protocol has had limited success. It was intended that a new protocol to the UNFCCC specifying commitments after 2012 be adopted in Copenhagen. This did not materialize due to stranding negotiations. The final agreement was merely a non-binding document between a limited group of countries.

[8] Adding other factors, such as impacts on the environment, human health and amplifying feedback will result in more severe consequences than initially estimated. Since poor regions carry a disproportionate burden, this would result in a total world average cost of a 20% reduction in consumption per capita (Stern, N., 2006).
[9] The UNFCCC was adopted at the United Nations Conference on Environment and Development (UNCED) ('Earth Summit') held in Rio de Janeiro (1992).
[10] Additional market based mechanisms were agreed upon in limiting emissions, with the purpose of promoting the most cost effective emissions reductions.

Most of the major difficulties in establishing successful collective action on a global scale stem from the inherent differences between nations (Horn, H., 2010). These factors all represent important considerations in the establishment of the institutions and governance structures for an international framework for collective action. (1) Benefits of abatement differ across countries. (2) The costs of a given amount of abatement differ across countries. (3) There are controversies concerning the time profile for policies - what utility discount rate should be used? (4) There are several complex moral and ethical issues that must be addressed – on what principles should the burden-sharing be based?[11] (5) Climate negotiations are likely to be economically or politically linked to other negotiations. [12]

Despite these rather dismal global achievements for climate change mitigation there are other more encouraging examples of collective action for preserving international commons. A notable example is the Antarctic Treaty (1959) preserving the marine eco-system around the continent. The success is often attributed to the fact that the Antarctic regime is an exclusive club, with a limited number of parties (Baylis, J., Smith, S., & Owens, P., 2008).

3. Theory

Though there are similarities, there are also significant differences between the two main types of collective actions problems, i.e. the open-access commons problem and the public goods problem (Sandler, T., & Arce, D., 2003).[13] The public goods problem is characterized by private costs and public benefits, while the commons are characterized by the opposite – public costs and private benefits. CPRs are a type of commons with the added characteristic of subtractability, due to crowding (Ostrom, E., 1990; Ostrom, E., et al., 1999; Aggrawal, V., & Dupont, C., 1999; Ternström, I., 2001). In other words, the amount one user withdraws from the resource limits its use by other users. While the management of the resource itself is a first-level collective action dilemma of the commons type, the effort to regulate its use is also a second-level dilemma of the public goods type (Bates, R., 1988).

In its simplest form, the public goods game is characterized as a Prisoner's dilemma (henceforth PD) (Sandler, T., & Arce, D., 2003), see chart 1 for a five-person illustration of the

[11] Developed countries have been part of creating the problem to a much larger extent than developing countries. Countries in the Southern hemisphere will however endure the consequences of climate change to a much larger extent. The US and China are furthermore currently responsible for an equal share of global GHG emissions even though China has a population four times as large. Should the costs of climate change still be born equally?
[12]Considerations of trade and efficiency are often involved in the climate debate. 'Going green' might furthermore cause severe restrictions on short term efficiency and therefore damaging international competitiveness.
[13] The public goods problem is sometimes also referred to as the contribution problem.

game. While the Pareto efficient outcome is that everyone contributes to the public good, the only Nash equilibrium is for no one to contribute.

Chart 1: Payoff matrix in the five-person public goods game (Sandler, T., & Arce, D., 2003).

	Number of contributors other than *i*				
	0	1	2	3	4
i does not contribute	***Nash*** 0	5	10	15	20
i contributes	-3	2	7	12	***Pareto*** 17

The commons game is also characterized by a PD game in its simplest form (Sandler, T., & Arce, D., 2003), see chart 2 for a similar five-person simulation. In the commons game, the Pareto efficient outcome is that all users restrain their use of the common resource, as opposed to maximizing their use. However, as illustrated by the chart, the only Nash equilibrium is that all users maximize their private benefits by also maximizing their use. Unless there is communication and credible commitments, this leads to the rapid depletion of the resource, or to "the Tragedy of the Commons". Since Hardin's influential article (1968), this name has signified the notion that users of open-access commons will overexploit the resource leading to its rapid depletion.[14] The general idea, however, dates back to Aristotle and Hobbes. The tragedy of the commons is a prime example of what Howard (1971) refers to as the first breakdown of rationality; individual rationality from all players involved in a game does not result in collective rationality.

Chart 2: Payoff matrix in the five-person commons game (Sandler, T., & Arce, D., 2003, slightly modified).

	Number of people other than *i* who withdraw resource units				
	0	1	2	3	4
i does not withdraw resource units	***Pareto*** 0	-5	-10	-15	-20
i withdraws resource units	3	-2	-7	-12	***Nash*** -17

Critics of Hardin and of Olson claim that there are many well-functioning regulatory systems for commons which do not rely on Hardin's proposed solution of assigning property rights (Ostrom, E. 1990, 2000; Ostrom, E., et al., 1999).[15] It has furthermore been established that commons as they get more complex are no longer best characterized as PD games. Instead they are best illustrated using other forms of coordination games, such as the chicken or

[14] Gordon (1954) who studied fisheries also came to the same conclusions as Hardin.
[15] They also point towards the miserable outcome of nationalization or privatization of previously communally managed resources.

assurance (Stag Hunt) games (Taylor, M., 1987). Ostrom is one of the most prominent scholars who oppose the notion that "individuals sharing a commons are inevitably caught in a trap [which leads to the overexploitation and destruction of the resource] from which they cannot escape" (Ostrom, E., 1990, p.14). Her main argument, first synthesized in *Governing the Commons* (1990) and refined in later publications (for instance Ostrom, E., 2000), is that sustainable institutional solutions for the management of local natural resource commons, although adapted to the particular situation, share certain characteristics which help them overcome the pitfalls of the "Tragedy of the Commons".

3.1. Ostrom's theoretical framework[16]

Ostrom's argument rests on a systematic evaluation of a selection of empirical studies of local CPR systems discussed by Martin (1989). All studies treat local environmental commons from communities of between 50 and 15 000 users, but come from a variety of academic disciplines as well as diverse geographic and cultural contexts.[17] Information was available on the resource itself, the appropriators' attributes and behavior, the rules and regulations in use as well as the resulting outcome (Ostrom, E., 1990, p. xv).

In Ostrom's terminology, *appropriation* is the harvesting of the resource, or deriving benefits from it. Those who appropriate are the *appropriators*. Ensuring that there is enough investment in the resource is referred to as *provision*. Ostrom's framework is based on a distinction of three different levels of decisions and therefore three levels of rules. *Constitutional rules* establish who is eligible to partake in the determining of the *collective-choice rules,* which in turn determines how the policies regarding the management of the resource are to be formulated. *Operational rules* are the actual policies regarding appropriation and provision. In this thesis, by 'rules' is here on out meant 'operational rules' unless otherwise noted.

In addition to the assumption of a local CPR on a small scale, the framework in *Governing the Commons* also rests on some further assumptions; that the CPR is renewable, that the resource is scarce rather than abundant and that there are no negative externalities on non-users (Ostrom, E., 1990, p.26). Ostrom defines a successful CPR management system as one which ensures the sustainability of the CPR, or as "institutions that enable individuals to achieve productive outcomes in situations where temptations to free-ride and shirk are ever present" (Ostrom, E., 1990, p.15). This implies that the users of a CPR must overcome three puzzles, which are nested

[16] Unless otherwise noted, the material in this section comes from Ostrom (1990).
[17] Cases based on extended fieldwork which had sufficient information on certain variables were studied in more detail for the purpose of establishing the theory.

within one another: "without monitoring, there can be no credible commitment; without credible commitment there is no reason to propose new rules" (Ostrom, E., 1990, p. 45).

Firstly, the users must overcome the puzzle of supply of the institutions, which in itself is a public good (Bates, R., 1988). The incentives to free-ride in the supply game, a second-order dilemma, could undermine the efforts to solve the first-order dilemma. However, with repeated games which establish trust and cooperation, there are ways to solving the dilemma of the supply of institutions (Bates, R., 1988; Ellingsen, T., 2009a; Wärneryd, K., 2009). Secondly, the users must overcome the puzzle of credible commitments. In other words, the users must find a way to incite people to consistently adhere to the rules over multiple time periods.[18] Finally, the users must find a way to monitor compliance with the rules (the puzzle of mutual monitoring). Traditional collective action theory predicts that the users will not find a way to monitor compliance as this is also a second-order dilemma. As monitoring becomes a public good, "for each member it --- [is] better to remain passive" (Elster, J., 1989, pp. 40-41).

Ostrom furthermore isolates four main problems that all CPR management systems must address. These are similar to the puzzles that successful CPRs have overcome, and include (1) how to cope with free-riding, (2) how to solve commitment problems, (3) how to arrange for the supply of new institutions and (4) how to monitor individual compliance with a set of rules.

Ostrom's main argument is that the successful CPR regimes have certain characteristics in common, which have helped them overcome these puzzles and problems. She presents in *Governing the Commons* (1990) eight design principles which tend to offer ways to solve these problems. By design principle, Ostrom means "an essential element or condition that helps to account for the success of these institutions in sustaining the CPRs and gaining compliance of generation after generation of appropriators to the rules in use" (Ostrom, E., 1990, p. 90). The operational rules are expected to be dynamic and be adapted to changing local conditions. A brief summary of Ostrom's (1990) design principles is provided.

1. Clearly defined boundaries

Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.

Ostrom claims that clear definitions are the first steps in organizing collective action for the preservation of a CPR, i.e. the first step in attempting to supply new institutions. Given that the resource permits effective exclusion of non-contributors, clear distinctions enables

[18] The incentive structure should therefore favor this course of action over a strategy of abiding by the rules in the first period only followed by defection. This would have allowed the appropriator to reap the benefits of the public good of preservation while not contributing itself.

controlling that only individuals providing to the upkeep of the resource can reap its benefits, thus increasing their incentives to collectively ensure the sustainability of the CPR.

2. Congruence between appropriation and provisions rules and local conditions

Appropriations rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money

Ostrom (1990) goes into detail on the importance of continuing adaptation of rules to the local conditions which increase the chances that the CPR system lasts. Ostrom briefly mentions that in successful CPR examples those users who are allowed to appropriate the largest proportion of the resource flows, also provide the most to the resource's upkeep. Generally this reduces the incentives to free-ride. She expanded (2000, p. 151) on this latter point; successful systems "effectively assign costs proportionate to benefits".

3. Collective-choice arrangements

Most individuals affected by the operational rules can participate in modifying the operational rules.

Ostrom stresses the importance that most of the individual users can influence the operational rules, in order to enhance adaptation to the local conditions. Later Ostrom (2000) also emphasizes that systems wherein this principle prevails are more likely to be considered fair by participants. This creates a sense of community which helps preserve the resource.

If the first three principles are respected, and the cost of changing the rules is relatively low, appropriators should be able to craft a set of good operational rules (Ostrom, E., 1990, p. 93).

4. Monitoring

Monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.

Ostrom is critical of scholars who assume readily available perfect information and thus assume away the problem of monitoring. The notion of *quasi-voluntary compliance*[19] has furthermore been found to illustrate the pattern of compliance in CPRs. Ostrom therefore maintains that there must be effective monitoring, in whose quality the appropriators have faith.

[19] Quasi-voluntary compliance is a concept which is based on the fact that an individual – faced with possibilities to evade the act of contributing but also with punishment if he is detected doing that – complies as long as he believes the outcome will be favorable if everyone complies and that the others also comply (Levi, M., 1988, cited in Ostrom, E. 1990, p. 95). It is therefore crucial that the individual has faith that violators are detected and punished.

In order to keep the cost of monitoring at an acceptable level, arrangements whereby the appropriators themselves share the burden doing the monitoring are suitable.

5. Graduated sanctions

Appropriators who violate the operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.

In order to incite the desired behavior, i.e. compliance with the rules under the notion of *quasi-voluntary compliance*, the fact that a violation is detected and punished is more important than the actual punishment imposed. Furthermore, the appropriators' faith in the system and the sense of community are crucial and therefore sanctions must be considered fair and proportional to the offense. In keeping with this, sanctions should start by being very light and increasing (Ostrom, E., 1990).

Ostrom maintains that a CPR system characterized by these first five design principles have good chance of solving the problems of commitment and monitoring simultaneously (Ostrom, E., 1990, p.99). These five design principles are supported by the three principles presented below:

6. Conflict-resolution mechanisms

Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.

Seemingly unambiguous rules can cause conflicts due to different interpretations. In order to reduce free-riding and to prevent internal conflict from causing the entire system to break down, it is important that there are mechanisms to resolve conflict. Functioning conflict-resolution mechanisms furthermore tend to increase compliance with the rules: "it is difficult to imagine how any complex system of rules could be maintained over time without such mechanism" (Ostrom, E., 1990, p.101). The crucial aspect is the preservation of the faith the appropriators have in the system, therefore the conflict-resolution mechanism must be considered fair and legitimate by them.

7. Minimal recognition of rights to organize

The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

Ostrom stresses that appropriators should be allowed to craft their own rules and enforce them without interference from external parties, such as governmental entities. This helps preserve the CPR management systems. Ostrom (2000) claims that forcibly imposing external rules is in fact a key factor that may destroy previously functioning CPRs.

8. (For CPRs that are parts of larger systems:) Nested enterprises

Appropriations, provisions, monitoring, enforcement, conflict-resolution, and governance activities are organized in multiple layers of nested enterprises.

Of the more complex systems studied by Ostrom (1990), all have management activities organized in multiple layers. Organizing the larger 'metasystem' into smaller 'subsystems' allows for a more efficient and tailor-made application of the previous design principles in each of the subsystems.[20] Thereby they are taking into account the fact that the management needs are different on each level as well as the fact that the local conditions relating to the resource varies between levels and between subsystems. Ostrom (1990) studied for instance complex irrigation systems, where there are different rules in the subsystems. She (1990) further stresses that although rules should differ in their technicalities, there must be appropriate rules on each level. If rules on one level are missing, the metasystem is incomplete and may not endure over time.

4. Analysis

4.1. Applicability of Ostrom's framework to climate change

The atmosphere is an open-access common resource – it is not possible to physically prevent someone from releasing GHGs into it. Assuming that the international community would like to limit the atmosphere's concentration of GHGs to a certain level, such as the 550 ppm CO_2e suggested by the Stern Review, the atmosphere can therefore be treated as a CPR. The emissions from one country will reduce the atmospheric capacity, i.e. it will limit what others can emit. Emitting is costless for countries (private benefit) while the entire international community shares the costs of damages caused by a changing climate (public cost). Thus it is likely that too much GHG emitted and the resource, i.e. the available room to emit, depleted.

The costs of reducing GHGs emissions – direct costs of abatement as well as the opportunity cost of foregone short term growth (Stern, N., 2006) – are private. The benefits in

[20] The terminology 'metasystem' and 'subsystem' is our own choice of words and are not expressed by Ostrom. We believe however that the terminology is appropriate in order to describe Ostrom's arguments.

the form of a stabilization of the GHG concentration, thus entailing a more stable climate, however accrue to all countries around the world. An international regime in order to address the issue of climate change, whereby the members of the international community agree to limit the emissions of GHG, is therefore best characterized as a public good (Olson, M., 1965). Following the established theory of public goods, contributions to the public good of GHG concentration stabilization, i.e. emissions reductions, will often be suboptimal.

With the atmosphere being an utterly overexploited commons, and with an inadequate supply of efforts to reduce emissions, most scholars agree that anthropogenic climate change is an expression of the "Tragedy of the Common" (Engel, K., & Saleska, S., 2005).

Discussing the lessons that can be drawn from successful management of local CPRs, Ostrom and co-authors (1999) conclude that the transformation to a global scale brings increased complexity.[21] The global scale implies problems due to the scaling-up of the issue, the cultural diversity among the participants, the fact that CPRs are interlinked, the accelerating rates of change, the requirement of unanimity for international collective action and the fact that we only have one globe with which to experiment.

The assumptions made by Ostrom about the nature of the CPRs (see 'Ostrom's theoretical framework') are satisfied for the issue of climate change caused by the changing concentration of GHGs in the atmosphere. Firstly, the atmosphere is indeed renewable, since the earth reabsorbs much of the CO_2 that is emitted.[22] The degree to which the Earth reabsorbs carbon dioxide is akin to the replenishment rate of a stock of other resources. Furthermore if the international community sincerely wishes to limit the concentration of GHGs in the atmosphere, there is limited room for emission. The third assumption is indirectly satisfied as well; everyone living on Planet Earth is a user of the resource and there are thus no non-users on which externalities can be enacted upon. It can therefore be concluded that the atmosphere can indeed be treated as a CPR, where the emissions of GHGs are equivalent to harvesting resource units.

The four problems that Ostrom has identified as those that all CPR systems must overcome are also problems that plague the mechanisms of the international community's response to climate change. How does the international community cope with the countries that do not contribute to the reduction of GHG emission? How can the international community ensure that countries make credible commitments about how much they are willing to reduce their emissions? How shall the international community establish the necessary new institutions?

[21] These results are in relation to global commons in general and are not purely related to climate change.
[22] The Earth reabsorbs about half of the CO_2 which is emitted (Stern, N., 2006). Other gases stay in the atmosphere for varying time spans. CO_2 is, despite the fact that other gases have much larger effect per unit emitted, the most important GHG due to the relative amounts of GHGs in the emission.

And finally, how can the compliance of individual nations be monitored? These issues stem to a large extent from the heterogeneity between countries.

If Ostrom's three-level-model of rules is applied to cuts in GHG emissions, the constitutional rules should be concerned with the composition of the assembly that will later decide on how to determine policy, and the collective-choice rules would in turn be how to determine policy on how to distribute emissions reductions, while the operational rules would be the actual policy on how much each country must cut its emissions of GHGs.

Before proceeding with the analysis of the design principles, it is interesting to ascertain whether the international community's barely 200 states could be considered to resemble close enough the communities with approximately 200 individuals studied by Ostrom. One view is that, if these states were all well-functioning and if their leaders could make credible commitments, that would in theory be the case (interview Prof. Tore Ellingsen 2009-04-29). Arrow (1963) has however, in what is usually referred to as the *impossibility theorem*, claimed that collective preferences should not be treated as aggregations of individual preferences; although individuals' preferences are always transitive, states' are not.

We are aware of these theoretical issues inherent in attempting to apply theory based on players acting as individuals to actors that are states. We do nonetheless believe that there are important insights to be drawn from investigating whether Ostrom's (1990) framework can be applied to the global scale. The general issues built into Ostrom's principles have already found certain expression in studies of the global scale. There is furthermore a general tendency in the literature to call for investigations of local collective action success in order to scale up efforts (Ostrom, E., et al., 1999; Dietz, T., Ostrom, E., & Stern, P., 2003). For these reasons, we will therefore proceed with our approach of investigating whether the local framework can be applied to the global level.

4.2. Introduction to analysis of design principles

Based on the 'background' section and the characteristics of the international community, the global environment to which these principles are applied can be viewed in game theoretic terms as one of an indefinite number of games, asymmetric information, asymmetric power distribution and possibility of coercion. There is also a reasonably high degree of uncertainty, and different actors have different strategy sets. This is different from the local level predominantly in the severe informational and power-based asymmetries and significant uncertainty between players. The uncertainty factor is especially enhanced in climate negotiation due to the lack of knowledge of future technologies, consequences, international relations between countries etc.

An essential similarity between the two frameworks on a global and a local level lies in the absence of a central authority, such as a government to impose rules and regulations. In effect, both aim at establishing a form of regime which promotes and supports the propagation of a cooperative solution to the CPR problem.

4.3. Design principle 1: Clearly defined boundaries

Ostrom maintains that the first step in crafting a system for the sustainable management of a CPR is to define who can appropriate from the resource and the boundaries of the resource itself. Transferring this to the global level and the preservation of the atmosphere implies that a climate treaty must specify both who the parties to whom the operational rules apply are and what ways of harvesting the resource (atmosphere) that are included. It is likely that any climate treaty would, in a manner similar to the Kyoto Protocol, be based on reductions of GHG emissions compared to a base line rather than on what absolute amounts each country is allowed to emit.[23] Thus the treaty would in effect be structured in a way that is the opposite of most CPR systems, which are often based on absolute limits on harvesting.

It is quite simple to define the resource stock if the international community can only decide on which concentration of GHG in the atmosphere shall be the limit.[24] Defining the ways of harvesting[25] is however much more complicated; should the definition for instance take only contemporary emissions into account or historic ones as well?[26]

Agreeing on definitions for the resource and the act of harvesting is a second-order dilemma (compare Bates, R. 1988). No country will want to take the first step in approaching the others' demands and thereby sacrificing some of their own demands regarding the definitions. Both self-serving biases[27] (Babcock, L., & Loewenstein, G., 1997) and strategic commitments (Schelling, T., 1956) play a role in perverting the negotiation processes. The party with the largest possibility to hold out will usually prevail in achieving its demands (Schelling, T., 1956). As with all negotiations, large amounts of real resources will be spent (Bhagwati, J., 1982). At the same time, Ostrom (1990) stresses the need for 'complete' definitions of the appropriators and of the

[23] For each reduction compared to a base line an absolute amount can always be calculated. We do however believe that the structure of the rules will be in the manner of the base line approach.
[24] This furthermore depends on there being ways of reliably determining the seasonally-adjusted concentration of GHG in the atmosphere, which there are.
[25] Remember that emitting GHGs is akin to harvesting resource units, as the emissions reduce the atmospheric capacity to absorb future emissions.
[26] Other important questions include: What GHGs should be included? What conversion scale should be used for converting non-CO2 GHG into CO2e? How should activities that reduce the reabsorption capabilities, such as deforestation, be treated?
[27] An example of such a bias could be that one's own emissions do not matter on the margin, or that the scientific evidence of the link between GHG emissions and climate change is not fully established.

resource itself. Nevertheless, it appears that due to the problems inherent in the second-order dilemma of defining the resource and the act of harvesting it might not necessarily be wise to strive for a fully complete agreement. This is due to the fact that the difficulties inherent in reaching an agreement on fully complete definitions may preclude the probability of reaching any agreement of GHG emissions reductions at all.

As pertains to defining the resource itself, due to the characteristics of the atmosphere there is no possibility to exclude non-contributors from appropriation. This could cause severe problems in achieving sufficient contributions for providing the public good. Non-excludability is an important factor in causing CPR management systems to fail,[28] but Ostrom (1990) maintains that boundaries are not the only factor determining success or failure. Nevertheless, the fact that there is no excludability heightens the importance of achieving global cooperation on the issue, as many scholars have maintained (Stern, N., 2006).

On the other hand, it is easier for small groups to jointly achieve productive levels of provision for the public good (Olson, M., 1965). Josephson and Wärneryd (2008) maintain that, given more than two players in the contribution game, there is always both an equilibrium with a positive number of contributors and an equilibrium with no contributors. When the cost of contributing is low enough and when group size is small, it is more likely that the equilibrium with a positive number of contributors is observed. Furthermore, Barrett (2006) asserts that when the number of parties becomes too large, international environmental agreements cannot improve on the non-cooperative outcome, i.e. the agreement cannot take the international community from the Nash equilibrium to the Pareto efficient outcome.[29]

There are somewhat counterintuitive conclusions to be drawn from combining the last two insights and the fact that some countries are responsible for a majority of emissions. Even though all emissions count for the concentration of GHG in the atmosphere, theoretically it appears that a treaty to which solely the large emitters are parties is preferable, particularly so if coordination problems are abundant. Including the smaller emitters may have a larger negative impact related to the group size than they have a positive impact related to the inclusion of all emissions.

This insight is further exacerbated by the fact that it is rational for players to view themselves as choosing last or conditioning their strategies on other players' moves (Howard, N., 1971, p.121). This could cause the structure of the process of agreeing on definitions to turn into

[28] The claim that non-excludability is the most crucial aspect in CPR management is made for example by Ciriacy-Wantrup and Bishop (1975, cited in Ostrom, E., 1990, p. 91).
[29] This is applicable when the game of providing the public good of environmental protection is structured as a PD game, which is what we have determined earlier (see 'theory').

a weakest-link game, whereby the least generous contribution from any player determines the contribution levels of the others as well. The fewer players there are in a weakest-link game, the easier it is to sustain Pareto efficient outcomes (Ellingsen, T., 2009c).

One insight that can be drawn from studying this design principle is that, contrary to the spirit of Ostrom's argument, leaving a slight bit of room for interpretation in the definition of harvesting might be beneficial since it increases the likelihood of coordinating on *any* definition. Furthermore, it might be beneficial if only a few countries/regions that are jointly responsible for a majority of global GHG emissions are parties to the treaty, especially if coordination problems are abundant. These insights do however in no way change the general implication that defining the resource and the parties of the treaty remains the starting point of crafting a global CPR management system.

4.4. Design principle 2: Congruence between appropriation and provisions rules and local conditions

Ostrom (1990) stresses the importance of adaptation to the local conditions. In a later publication (2000, pp. 149-150), she also emphasizes that "the local rules-in-use --- [should] allocate benefits proportional to required inputs." It appears to be difficult to transfer Ostrom's original principle of adaptation to local conditions to the global level exactly as it is. On the other hand, it is also necessary for the international community to craft operational rules that divide the burden of climate change mitigation in a proportional and equitable way, one that "effectively assign costs proportionate to benefits" (Ostrom, E., 2000, p. 151).

Ostrom bases her theory on local resources within small comparatively homogenous communities. "Local conditions" loses its conciseness as a concept when transferred to the global scale, largely due to the heterogeneity of the parties involved. The starting points for the parties are very divergent with regards to their economic and political situations. There are substantial asymmetries in power and in how climate change will affect countries. There is much variation in the sources of emissions throughout the world, and therefore large discrepancies in what reductions that can realistically be made and what costs these would entail. The insight that can be transferred from this is that the rules contained in the international treaty should be flexible enough to be adaptable to the situation of every country. The rules should therefore mandate only the quantity of the reduction and not specify method of reduction. This is already implicit in the major existing international treaties on climate change.

There are striking resemblances between the dividing of costs in climate change mitigation and the dividing of the defense burden within a military alliance. This subject has been thoroughly studied beginning with the 1966 publication of Olson and Zeckhauser's "An

Economic Theory of Alliances", which was to a large extent based on Olson (1965). The same logic is applicable to many other international organizations and causes as well, such as UN Peacekeeping or WHO funding (Sandler, T., & Hartley, K., 2001).

Olson and Zeckhauser (1966) formulated the *exploitation hypothesis*, or that large members of alliances are exploited by their smaller allies and therefore carry a disproportionate share of the defense burden. Olson and Zeckhauser (1966) treat military spending as a pure public good, i.e. exclude the possibility of ally-specific benefits from having a large military. This notion of exploitation still endures in relation to many global issues (Sandler, T., & Hartley, K., 2001). Later studies on the burden sharing in military alliances have however refined the analysis; see Sandler and Hartley (2001) for a summary. They have included the possibility of military spending resulting in ally-specific benefits in addition to the public good of alliance-wide deterrence, i.e. treating defense spending as a joint product, of which only some parts are public goods. The existence of ally-specific benefits should make sufficient contributions from smaller parties more likely and thus result in "a greater match between benefits received and burdens carried" (Sandler, T., & Hartley, K., 2001, p. 878).

Sandler and Hartley (2001) do in fact briefly address GHG reductions and argue that they are a pure public good, not a joint product. At the same time however they argue that a joint product model is applicable if the ratio of private benefits to total benefits is significantly different from zero. There is a tendency for both policy makers and the public to treat efforts aimed at reducing GHG emissions as pure public goods, thus neglecting to see the benefits on other levels (Ostrom, E., 2009). After all, the efforts and investments put in place to reduce the GHG emission have positive externalities on multiple levels, which are the equivalent to ally-specific benefits.[30] Thus by enlarging the perspective and emphasizing associated private benefits the perceived game of GHG emissions reductions can be changed. The larger parties, which also have larger potential cost saving and other private benefits, therefore have larger absolute private benefits which do not benefit other players.

How to share the burden of GHG emissions reductions is a matter associated with, among other issues, substantial ethical and moral questions. It is not possible for us to have a thorough discussion on those matters here; they merit a substantial analysis which is beyond the scope if this paper. It is however expected that within alliances the countries with a larger demand for the alliance's public good will contribute relatively more, i.e. as a share of total

[30] For instance, increasing fuel economy standards in the transport sector leads to reduction in GHG emissions (global level), less reliance on often foreign oil (national level), less local environmental degradation, such as NOX-gases pollution (local/regional level) and cost savings for individuals and businesses. All of these benefits, except the actual GHG reductions, are private within the alliance.

expenditures (Sandler, T., & Hartley, K., 2001). Furthermore, if a more well-off country has the same demand for the alliance good as a less well-off ally, the absolute contribution from the more well-off country will be larger. Similarly, transferring this to GHG emissions reductions implies that larger absolute cuts of emissions should come from the more affluent countries. A balance between the relative demand for climate change mitigation and ability to reduce GHG emissions must thus be struck, while taking matters of equity into account.

Though it cannot be directly transferred and would in any case need to be concretized first, there are transferable insights from this design principle. If states include private benefits when evaluating costs versus benefits, the perceived disproportionality between the GHG emissions reductions of different countries can be reduced. When private benefits are taken into account a climate treaty is more likely to be agreed upon and the suboptimality in the provision of emissions reduction is reduced.

4.5. Design principle 3: Collective-choice arrangements

Ostrom stresses the need for collective-choice arrangements whereby all appropriators have a possibility to take part in formulating the policy. Ostrom's main argument for suggesting this is that systems embodying this principle are better suited for adapting the operational rules to changing local conditions. On a global scale this could imply renegotiation of the emissions reductions mandated for each country with regular intervals.[31] Due to the fact that the most common principle in international law is voluntary adherence to international treaties, these collective-choice arrangements further imply that every country would have *de facto* veto power over their own GHG reductions in each renegotiation round.

The ample literature on negotiations provides valuable insights as to the outcome of these collective-choice arrangements. Assuming that total global reduction in GHG emissions must be achieved by distributing the burden of emissions reductions on the individual countries, literature on negotiations to distribute something among the players can analogously be applied. The normal case of such negotiations is that each actor wants as much as possible of the pie (Ellingsen, T., 2009b). In the analogous application, the whole amount should still be distributed although the actors involved now want to have as little as possible distributed to themselves.

[31] The constitutional rules specify the total global emissions reductions and would not be renegotiated.

Negotiations will come to a standstill until one of the parties gives in to the others' demands (Schelling, T., 1956). The party most prepared to harm itself in the short run has the highest bargaining power, which ultimately leads to the best long run outcome. The party most dependent on there being an agreement loses out in the eventual agreement.[32] Commitments – demanding that a mandated reduction cannot exceed a certain level – must be credible in order to have an effect in the negotiations. Considering that while actors can stall negotiations and even withdraw from international treaties they cannot be excluded from using the resource, commitments not to sign are therefore more or less credible. It is the commitments from those countries that are more dependent on the others providing that are less credible (Olson, M., & Zeckhauser, R., 1966).

Chart 3: A simplified illustration of the negotiations of burden sharing regarding GHG emissions cuts

		Player B	
		R_A	R_B
Player A	R_A	2 | 1	0 | 0
	R_B	0 | 0	2 | 1

R_A: Rules for emissions reductions that benefit player A relatively more than player B

R_B: Rules for emissions reductions that benefit player B relatively more than player A

The negotiations on how to divide the GHG emissions reductions can somewhat simplified be illustrated as a Battle of the Sexes coordination game, see chart 3. Both players want the reductions, but would like them to happen in a way which benefits themselves in relative terms, thus hurting the other. Player A prefers the rules for GHG emissions reductions that benefits it relatively more than player B, i.e. R_A. Player B similarly prefers R_B. It is important however to remember that although it has been claimed that countries care more about relative than absolute gains (Snidal, D., 1991; Mosher, J., 2003; Rousseau, D., 2002), the coordination game is not a zero-sum game. In absolute terms, all players benefit from there being an agreement, regardless of how the actual reductions are distributed among them. There can be significant power asymmetries between the players. The player with the higher bargaining power has the first-mover advantage, i.e. the authority to choose his strategy first, and rationally chooses to insist on a reduction pattern that benefits itself (Ellingsen, T., 2009c). Therefore, the player more dependent on there being a treaty has to choose between no treaty at all or agreeing to a way that hurts itself.

Developing countries represent only a small share of the global emissions, while they bear the majority of the damages caused by it. Therefore they arguably have a larger demand for action

[32] Schelling (1956) defines bargaining power as the "power to blind oneself".

on climate change mitigation. Theory also suggests that the developing countries have less bargaining power and will be taken advantage of in every round of negotiation.[33]

The situation of stranding negotiations is exacerbated by the fact that it is rational for actors to view themselves as choosing their strategy last of all the actors (Howard, N., 1971, p. 121). This means that it is also rational for the actors to condition their strategies on the strategies of others, thereby prolonging the process of negotiation. Another concern that might complicate the coordination on a strategy of reducing GHG emissions is that countries have asymmetric information regarding the issue as well as the fact that they have different strategy sets (Morrow, J., 1994). This is due to their inherent ability and preference differences. Furthermore, the more complex a negotiation system becomes, the longer the decision-making will take (Olson, M., 1982). The process of international negotiations is time-consuming and uses up real resources that could have been spent for productive purposes (Bhagwati, J., 1982).

The research on intertemporal consumption choice and on hyperbolic discounting[34] can provide further insights on why implementing this design principle might have adverse effects. Without commitment, there will be too much GHGs emitted in the first time period at the expense of future periods (Ellingsen, T., 2009d; Strotz, R.H., 1955-1956).[35] At the start of the next time period, the same situation and result will ensue, only that there is even less atmospheric capacity in which to emit. Thus, there are incentives for each of the actors to postpone the reductions in GHG emissions. Similarly, Akerlof (1991) maintains that actors seem to have a tendency to procrastinate, i.e. to postpone uncomfortable but necessary actions. These problems manifest themselves both on the level of committing to reductions and, perhaps especially, on the level of putting the necessary measures into action.

A further complexity-adding characteristic is the fact that there may be policy changes in member states between negotiation rounds. When individual preferences are aggregated to form social choices, such as the decision-making in democratic countries, it is perfectly rational for the policy to alternate between two extremes (Arrow, K., 1963; Howard, N., 1971). If public opinion favors arms reduction it is likely that there will be a reduction in armament. The reduction in arms, however, strengthens those who oppose arms reductions, thereby causing the process of arms reductions to come to halt (Howard, N., 1971). Combating climate change is also a policy

[33] They furthermore have less financial resources, in general, to spend on adaptation. The developing countries are therefore arguably more dependent on there being a climate treaty which reduces global emissions of GHG. They can furthermore not hold out as long in the negotiations, both for reasons related to the relatively higher urgency of achieving GHG emissions reductions and due to the fact that international negotiation processes are very expensive for the parties involved.
[34] Hyperbolic discounting is a way to illustrate time inconsistent preferences by attributing less importance to utility in the future.
[35] Emitting today is analogous to consuming the available room for future GHG emissions.

issue mostly driven by public opinion and could therefore be susceptible to the same policy development.

Given this kind of likely behavior it is possible to consider the international community as having two selves: (1) the international community in the current time negotiation round, and (2) the international community in the next negotiation round. The international community should in the current negotiation round be aware that it faces these incentives and should therefore try to "bind itself to the mast", i.e. remove the possibility to deviate in the next period from what they believe to be the correct strategy now (Schelling, T., 1984; 1985). This could be done by binding contracts, coupled with effective monitoring and sanctioning (see design principles 4-5). Therefore, the international community would likely be more successful if it could 'bind itself to the mast' by not renegotiating the reductions in GHG emissions too often.

From an empirical perspective, there are other aspects regarding climate change which seem to suggest that the mandated emissions reductions should be more stable. There are significant time lags involved, both climatology-related lags and lags in implementation.[36] Therefore, there must be long-term planning at all levels of decision-making. Postponing action on emissions reductions furthermore entails significant ethical and moral issues due to the intergenerational concerns involved. As important as they are, these are however beyond the scope of this thesis.

The insights that can be drawn from the probable outcome of implementing this design principle imply that this principle cannot be transferred directly to a global level. Rather the insights seem to suggest that the international community should not implement collective-choice arrangements based on Ostrom's principle, since it could incite pushing the problem of climate change mitigation forward. Ostrom's reason for suggesting these arrangements is however aiming at incorporating an ability to adapt to changing local conditions. It is therefore desirable that the collective-choice arrangement will be rigid to prevent procrastination, but at the same time flexible enough for the international community to 'tweak' the system as the understanding of climate change deepens.

4.6. Design principles 4-5: Monitoring and Graduated sanctions

Ostrom (1990) claims that the principles of monitoring and graduated sanctions are inherent to each other, and they both deal with the enforcement of cooperative solutions. To a certain degree these problems exacerbate one another. It is difficult to apply proper sanctioning

[36] The current emissions reductions will have detectable effects on the climate only in 40-50 years from today. Actors down the line, who will do the actual emissions reduction, require stability to make large investments in low-emissions technology (Stern, N., 2006).

when there is a problem of monitoring (Morrow, J., 1994; Bendor, J., 1987).[37] Similar to what has already been argued under previous design principles, monitoring and sanctioning are second-order dilemmas (Elster, J., 1989).

Applying these principles on a global arena would imply significant adjustments from Ostrom's original formulation, and it is not clear how to develop an optimal structure of enforcement and monitoring. The analysis will therefore be divided into three segments, each of which discusses a form of providing the public goods of monitoring and sanctioning. Alternative one is a situation where the burden of enforcement is left to the appropriators, i.e. the nations themselves, without creating any specialized overarching institutions. This is essentially the way Ostrom had intended for the principles to be enforced at a local level. Alternatives two and three explore the notions of international leadership and of creating an institutional body for enforcement.

4.6.1. Voluntary commitments and multilateral negotiations between nations

In discussing principles four and five, Ostrom maintains that the provision of monitoring and sanctioning occurs on the grounds of a quasi-voluntary compliance,[38] which indicates indirectly that the commitment to provide monitoring and sanctioning should to some extent occur on a voluntary basis. Though it is cumbersome to characterize this within the global framework with an asymmetry of information, a skewed distribution of power, an indefinite number of games and high interdependence between significant issues, certain progress has nonetheless been made (Bendor, J., 1987).

Acknowledging that the two strategies tit-for-tat and trigger can be seen from an enabling perspective in the sense that they promote cooperation in the long run; in a multi period-game under the threat of retaliatory action all players will choose the cooperative outcome in the PD game. A short-run relative gain will not yield sufficient benefits for the defecting party if there are significant repercussions for their actions. Ultimately, in the long run, appropriators will expect the benefits of upholding the norms of sanctioning and monitoring to exceed any short run relative losses incurred by penalizing the defecting parties. The situation can therefore be characterized as one where "ex ante rationality in the short run parallels the norm of diffuse reciprocity" (Morrow, J., 1994, p. 409). It is however difficult to see that reciprocity as represented by a tit-for-tat or trigger strategies can be applied to the complex multilateral negotiations of climate preservation on a global scale. Still, the mechanisms of these strategies can

[37] This is also why Ostrom have a joint discussion of both principles. We have similarly decided to merge them.
[38] See footnote 20.

give useful insights on the possibilities to apply monitoring and sanctioning activities to a global scale.

If the trigger strategy is employed, a defection by one country can imply that each country applies the non-cooperative outcome for ever, i.e. in effect that the system breaks down. This would be a strong force in preventing cheating and enforcing cooperation (Barrett, S., 1991). The unforgiving nature of the strategy can however prove to be more harmful than beneficial, in the long run. Once again the role of fluctuations and external factors could impact whether a country defects (see design principle 3 for a discussion on the role of ideological fluctuations). Fluctuations, regardless of their type, are a powerful force in this scenario since a singular infraction could be detrimental to long-term cooperation. Seemingly in this aspect the tit-for-tat strategy yields a more beneficial outcome.

An approach which combines aspects from these two strategies was presented by Barrett (1991) in his study of international environmental agreements. He argues that if one country reduces its contribution to the public good all other countries will do the same, effectively attempting to punish the defector. Likewise, if another country accesses the agreement, or if a country increases its abatement, all other countries will increase their GHG emissions reductions as well. In this case, given that a country is committed to the goal of overall reductions in emissions, it cannot do better than to stay in the agreement, thus yielding a stable Nash equilibrium outcome. This requires a great deal of fluidity and flexibility within the system. It would however be difficult for countries with different constraints on strategies in continuous fluctuations and in political environments to adapt to such a system on an ongoing basis.

Multilateral negotiations with voluntary commitments can be described using the Folk theorem i.e. in a situation with repeated games any outcome is a feasible solution concept given that the players satisfy their minimax conditions. Ultimately, sufficiently patient appropriators may adopt strategies that improve joint outcomes (Ostrom, E., Gardner, R., & Walker, J., 1994). The Folk theorem also gives a more optimistic view on the chances of sustaining long term cooperation. "Any outcome where both players receive at least as much as their minimax value in the stage game can be supported by a punishment strategy provided that discount factors are not too high" (Morrow, J., 1994, p.402). However, the empirical and theoretical uncertainty, with which discount factors is ridden, provides a significant difficulty in establishing cooperation in the enforcement of punishment strategies.

Adding uncertainty to the above postulations can considerably alter the probability of a cooperative outcome. Barrett (2006) has even posited the view that in a world with a high degree of uncertainty a cooperative outcome is not significantly more fruitful than an uncooperative one.

A way of addressing the issue might be extensive monitoring activities between nations. In a situation of almost perfect monitoring there could however still be a problem of cooperation; the information transmitted by monitors, could fail to account for the underlying reasons why a particular infraction has occurred. This yields to the idea that decisions are based upon subjective rationality rather than objective (Howard, N., 1971), which could create a major divergence from the Pareto optimal cooperative outcome. Furthermore, even with perfect information about the occurrence of an infraction by a certain random player, the possibility to weight different strategies as to the most appropriate punishment is subject to significant cognitive constraints. The sheer complexity of international relations and issue interdependence makes it difficult to foresee the possible consequences of a sanction. All potential sanctions must be considered for their current costs and consequences, but also be weighted upon future benefits of mutual compliance and current costs of deterrence.

Is it then legitimate to conclude that sanctioning is the core of the problem when these two principles are transferred to a global scale? There are some discrepancies between the result of uncertainty predicted by the theory and what the empirical material suggests. Individual countries are seldomly pointed out and/or sanctioned for singular infractions of excessive emissions. Countries can be monitored by satellites and GHG emissions can be approximated to quite a high degree of certainty. As regards the climate issue NGOs, researchers, media and communications act like a third party enforcement mechanism and have built transparency into the global system. This alleviates the process of monitoring and makes it less costly. It is important to note that the uncertainty as regards to fluctuations in political and economic structures within countries ultimately drives changing policies at a global level. With this in mind we have to conclude that sanctioning is more of a problematic issue than is monitoring.

4.6.2. Leadership

An interesting aspect of the climate issue as of today is that the Kyoto Protocol splits the international community into Annex I and Annex II countries where it is implicit that Annex I countries are supposed to lead by example and pave the way for Annex II countries. Such an arrangement has significant benefits as it creates self-sustaining expectations (Keohane, R., 1982; Morrow, J., 1994). Consequently regimes under leadership persist because they are in both actors' interests. A cooperative outcome is achieved with a greater likelihood if there are benefits allocated to the party assuming the leading/hegemonic role (Morrow, J., 1994). It is therefore interesting to examine the idea where a group of nations take the leading role for sanctioning and

monitoring, all in coherence with Ostrom's idea where several parties are assigned by the community to pursue monitoring and sanctioning activities.

There has been significant controversy regarding what group size is optimal in establishing cooperation for monitoring and sanctioning. Agrawal (2001) for example claims that the costs of monitoring rise exponentially as group size increases. Medium-sized groups are more likely to provide third-party monitoring. There are thus positive benefits in establishing an exclusive, medium-sized group of nations responsible for enforcement that would enable a higher degree of credibility in the threat of sanctioning. Furthermore, the sheer availability of credible sanctioning measures could have a disciplinary effect on actors (Fehr, E., & Gächter, S., 2000). A point of consideration in this context is the probability with which all nations would be willing to succumb to such a system. Without universal agreement to this settlement there is a risk that the system would fall apart (Kosfeld, M., Okada, A., & Riedl, A., 2009). The commitment problem is detrimental and its solution is a prerequisite for establishing legitimacy and credibility.

Another way of applying this structure to global emissions reductions is building a group of nations that would voluntarily form a club where internal sanctions for defection are imposed (Kosfeld, M., Okada, A., & Riedl, A., 2009). If they formed a small group adhering to a pre-defined regime, the major parties responsible for annual volume of emissions such as the USA, China, EU, Canada, Russia, Brazil and India would do a significant contribution to alleviate the strain on the atmosphere.[39] In this case emphasis is placed on reciprocity at a different level: "although the smaller actors have the potential to act as free-riders, efforts are made to ensure that they have incentives not to do so for the fear that they will suffer in a larger game" (Axelrod, R., & Keohane, R., 1985, p. 247) (see also design principle 2).

The constellation seems however difficult to uphold. The countries that are chiefly responsible for emissions are often interlinked by complex economical, political and security relationships. Sanctioning another country could therefore entail a cost that would exceed anything within the realms of credibility effectively rendering the possibility of sanctions futile in establishing cooperation.

To conclude, although this type of constellation for monitoring and sanctioning does not really deal with the problem of uncertainty in the sense discussed above, it can constitute an improvement from the unorganized form of arranging monitoring and sanctioning initiatives. The problems in these constellations of governance do however deal with the changing global power structure and the problems of issue interdependence – challenges that seem difficult to

[39] Having a group of leading nations in the aspect of environmental preservation could also yield to more concentrated efforts in research and the establishment of power centers in structural, entrepreneurial and intellectual leadership. See Young (1991).

circumvent in an efficient fashion. They can therefore pose a major difficulty in applying Ostrom's principle four and five of monitoring and sanctioning to a global scale.

4.6.3. Institutional framework for monitoring and sanctioning

Unlike the above two examples, setting monitoring and sanctioning functions within the context of an institutional framework can significantly alleviate the flow of information and the standardization of norm setting processes and cooperation (Keohane, R., 1982) It is important to keep in mind the fact that creating an external institutional framework to carry out sanctioning and monitoring functions is not what Ostrom (1990) propagated in her original design principles. Nevertheless, it could potentially be very useful to the large-scale cooperation required on a global scale.

"Each actor requires assurance that the other will also eschew its rational choice (and will not cheat, and) such collaboration requires a degree of formalization. The regime must specify what constitutes cooperation and what constitutes cheating" (Stein, A., 1982, p. 312). Without this kind of formalization the rectification of long-term cooperation would be difficult to achieve and sustain. Similarly, when pay-off structures are much like those of the PD game, players will attempt to institutionalize reciprocity. In this way players will be able to draw advantage from other players' uses of strategy as well (Keohane, R., 1982). Furthermore, such an arrangement is beneficial as it establishes mutual expectations about the patterns of behavior and gives a sense of consistency in the interactions between the parties. With constant change in issues ranging from international relations, uncertainty and discount factors, this is especially important.

"Generalized commitments within the framework can cope with conflictual implications of uncertainty by imposing favorable assumptions about others future behavior" (Keohane, R., 1982, p.35). Therefore, contrary to the situation without institutions, this approach directly targets the issue of uncertainty. An institutional framework diminishes the room for players to embark upon widely different strategies. If a state chooses to pursue a different environmental policy, the global institutional framework could impose significant constraints on the strategies that are available to the nation. This creates a more structured and targeted approach to tackling the climate issue and deals directly with political fluctuations.

Furthermore, within an institutional framework the threat of sanctions could be imposed with greater legitimacy and can have a higher impact in the sense of prophylactic deterrence of emissions. The threat of sanctioning would receive a greater credibility given there is a standardized framework within which there is no exception to the punishment of free-riding or non-cooperation. It can further be maintained that an institutional framework lifts, to a certain

degree, the cognitive constraints of individual players and enables the implementation of a standardized system of graduated sanctions, all in accordance with Ostrom's general description of the successful maintenance of a CPR regime.

Barrett (1991) maintains that credibility is a significant problem in enforcing international environmental agreements. Contemplating the credibility of sustaining the institutional framework can cause difficulty in getting nations to commit to the system.[40] The greater importance the players assign to the future the greater their willingness to commit to such a system. At the moment however there is significant controversy in what importance that should be attributed to the future, mainly embodied by the extensive discussions of the rate utility discounting (see 'previous study'). Ultimately, without realization of the severity of the problem and of the concrete benefits of committing to a system, not enough will be done in the form of contributing resources to a system of monitoring and sanctioning.

It is difficult to draw any general insights from transferring this principle, as the implications of it depends so vastly on the choice of constellation for enforcement. Although there are major difficulties in the implementation, it has been found that enforcement activities in the form of monitoring and sanctioning are, at least theoretically, applicable to a large extent on a global scale. From an empirical perspective, issue interdependence is arguably the most important concern. It can also be concluded that the issue of sanctioning is more pressing than the issue of monitoring in the international system to limit the GHG concentration in the atmosphere.

4.7. Design principle 6: Conflict-resolution mechanisms

Ostrom (1990) stresses that, in order to prevent internal conflict from causing the entire system to break down, it is important that there are mechanisms to resolve disputes. Diamond (2005) similarly maintains that the reason for resource collapses lie in insufficient institutions. It is also notable that the trigger strategy (see design principles 4-5) implies that a single infraction, possibly caused by fluctuations in the exogenous environment, could lead to a collapse of the whole system. This situation is exacerbated by the fact that the infraction can be based upon subjective rationality where "a decision-maker cannot be convinced that she is wrong in making [the decisions]" (Gilboa, I., et al., 2010, p. 755). This can most clearly be seen in the context of self-serving biases and in the examination of to what extent they skew the expectations and

[40] On an empirical note however it is mentionable that the European Union has succeeded in similar institutions to enforce environmental agreements even with a certain degree of uncertainty as regards the future. This leaves a hopeful note on the possibility of applying such a system even to the global scale.

perceptions of actors.[41] These conclusions stress the importance of having conflict-resolution mechanisms that yield a more targeted approach to addressing different points of view on emissions reductions. To a certain degree problems arising due to issue interdependence and subjective rationality can thus be eliminated. These advantages seem to yield benefits which likely make countries more willing to commit to the entire CPR management system, thus highlighting the importance of an external, neutral global body to pass judgment on each individual case. It can thereby help maintain the legitimacy of the system.

A careful consideration has to be given to the dynamics of decision-making in a conflict situation, such as a decision to sanction a player. Usually decisions on a global level between nations are made on the basis of unanimity rule, as opposed to majoritarian rule, with imperfect information about the welfare frontier, while focusing primarily on key issues (Haas, M., 1992). Committing to a system, where judgment on what is deemed 'right' is given within a multilateral arena of conflict-resolution, does therefore not implicate that a nation must be passive in decisions targeted towards it by other nations. Furthermore, similar to the case in many of the local CPRs in Ostrom (1990) where there is no overarching authority, there is no world government that can rule whether an infraction of international law has occurred.[42] Hence a system like this on a global scale could in reality be rendered ineffectual by the influence of certain powerful nations. Although this can be seen as a major problem it is not impossible to circumvent, especially with the establishment of strong institutions that are considered legitimate and credible.

Another approach, which implicitly embodies the same principle, is to form and maintain an external body to gather sufficient information and pass judgment on suspected infractions. This could be in the sense of distributing 'name and shame' punishments on infracting parties (Rischard, J-F., 2002).[43] Functions like this could be attributed to organizations such as UNEP, WTO, IPCC and the WWF. Thus it can be seen that the general framework is set for the application of design principle 6, given that nations are willing to recognize the authority of this body to pass judgment on whether an infraction has occurred.

Giving right to a certain party in such neutral arenas of conflict-resolution ensures a higher legitimacy in imposing sanctions on a certain party, as well as a higher degree of credibility in imposing a threat. It is however not evident that these arenas of conflict-resolution, or

[41] It can for example be maintained that a country with large emissions will see the issue of preserving the environment to be of secondary importance.
[42] A country that violates a treaty can be taken to the International Court of Justice – but only if the country agrees to go. Even then the country can refuse to comply with the court's decision.
[43] Effectively this also yields a high degree of importance to the citizens in giving them the power to either condemn or praise a nation or corporation.

mechanisms of giving 'right', directly be coupled to the authority of explicit sanctioning. Rather, they could take a 'fact-finding' function aiding other parties or mechanism in charge of the actual sanctioning. It is most probable that the function of conflict-resolution be coupled with the third constellation of monitoring and sanctioning, i.e. with an institutional framework for enforcement (see design principle 4-5).

Generally it appears that this principle can, to a significant extent, be transferred to the global scale either as an institutional arena taking the form of a tribunal or as an external body passing judgment based on objective information. The transferability is however conditioned upon the international community being prepared to succumb to the authority of the conflict-resolution mechanism.

4.8. Design principle 7: Minimal recognition of rights to organize

The overarching idea is that appropriators should be allowed to organize themselves in a way they find suitable, without outside interference. Outside interference tends to reduce the adaption to the prevailing local conditions, which thus reduces the efficiency of the CPR management system. Transferring this idea could entail changing the collective-choice rules so that the system for dealing with the preservation of the atmosphere is depoliticized, both regarding policy making and the actual monitoring and sanctioning activities. By depoliticized it is meant that the decisions regarding the operational rules should be taken by experts in fields related to climate change mitigation and adaptation rather than by the politicians. The experts would however likely receive some objectives (constitutional rules) from the politicians as it is they who enter into international agreements.

Due to the habits of academia to remove the context of the issue, the idea of a depoliticized, independent authority is in fact implicit in most of the concepts employed thus far in the analysis. Payoffs of strategies normally only take the specific issue, and sometimes directly related ones, into account. Had this been the case in reality, there would be no need for a depoliticized organ. The approach to assume away the context has however been criticized for instance by Ostrom (1990).

In reality, however, international relations are not concerned solely with any specific issue. Countries have at any one time ongoing relations with many, if not all, other countries either directly or indirectly on a myriad of issues so there is substantial issue interdependence (see design principles 4-5). Real world payoffs therefore include outcomes of several bargains. Continuing and intersecting negotiations makes threats from parties with overall large bargaining power more credible at the same time as it makes 'horse-trading' more likely (Schelling, T., 1956).

Politicians also tend to interfere using discretionary policies that are short-sighted, and thereby achieving short term gains but at the same time causing long-term problems (Barro, R., & Gordon, D., 1983, on monetary policy). Independent central banks acting under monetary policy targets have been proven to achieve more stable long term policies (Rogoff, K., 1985).

If issues of dividing the reductions of GHG emissions between countries could be delegated to a depoliticized decision-making organ free from outside interference and concerned only with climate change mitigation and adaptation, similar to independent central banks setting the monetary policy, the harmful side-effects could be reduced. The international community would thus set an overall reductions target, i.e. the constitutional rules, which would then be divided among the nations by the independent organ. This could lead to more efficient, more equitable outcomes of climate negotiations as well as executive activities, and therefore better preserve the atmosphere. Delegating policy-making could also be a way for governments to 'bind the current and future administrations to the mast' (see design principle 3) and reduce incentives to postpone action on climate change.[44]

The important insight transferable to a global system for preservation of the atmosphere from this design principle therefore concerns the non-interference from governments in the policy-making regarding the issue, i.e. the setting of the operational rules on GHG emissions reductions. One way of achieving this could be to delegate authority to a fully independent committee, preferably made up of experts in fields related to climate change, i.e. providing the necessary knowledge regarding how to feasibly reduce the emissions of GHGs. Thereby, in the spirit of Ostrom's original design principle, the policies can be better tailored to the local conditions of emissions reductions.

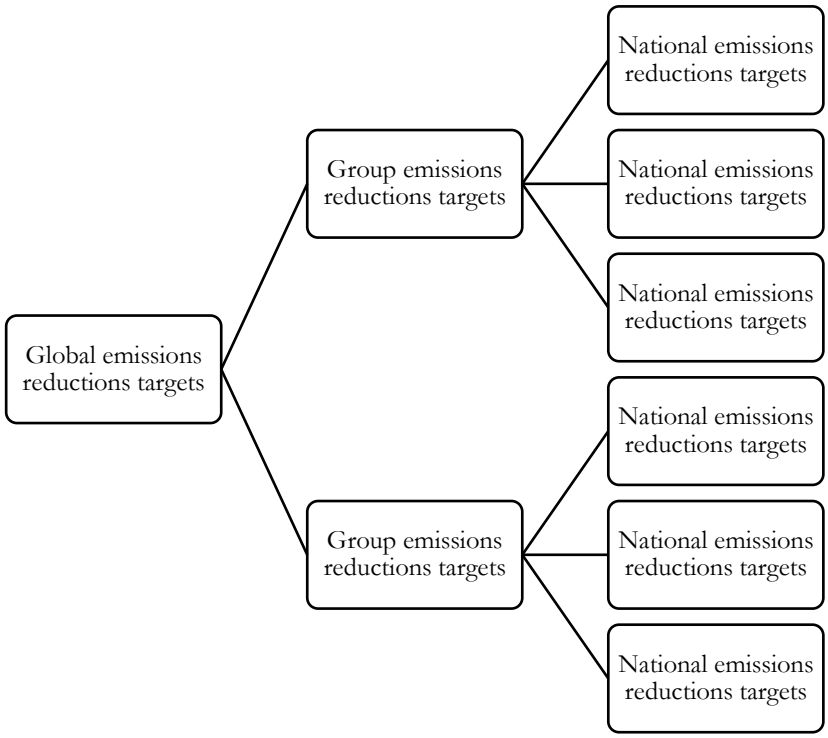
Unfortunately, it is not very realistic that governments will surrender this authority. Climate change and its mitigation involve significant costs, consequences, and necessitate large structural changes (Stern, N., 2006) over which the governments would like to have control. Most governments have short mandate periods and are therefore shortsighted. They prefer to retain flexibility and adopt easily reversible commitments (Bernhard, W., and Leblang, D., 1999). Countries will furthermore likely be wary of submitting to a supranational expert committee for binding policy-making, the norm being that international treaties are based on voluntary adherence due to concerns related to sovereignty.

[44] Discretionary postponement of action on climate change is in our analogy comparable to discretionary monetary policy; see Barro and Gordon (1983).

4.9. Design principle 8: Nested enterprises

Ostrom's whole philosophy could be interpreted as managing the commons in small communities and later scaling up efforts if the system works well. Ostrom (2009) furthermore advocates for a "polycentric solution" to the issue of climate change. There would be both actions and rules concerning GHG emissions on multiple levels. Thus, a joint international solution is perhaps not necessary, although it is desirable. Transferring Ostrom's (1990) design principle to the global level could be seen as implying dividing the international community into a few groups, each group being assigned a certain reduction of GHG emissions.[45] The group's members would thereafter divide the reductions between themselves, see chart 4. This system can be compared to the irrigation systems studied by Ostrom (1990), where there are differing operational rules for locations within the same system due to varying conditions. Similarly, countries operate under different resource constraints and face varying consequences of climate change.

Chart 4: A 'nested enterprises' approach to GHG emissions reductions



The nested enterprises could be implemented so that the group members are collectively responsible for achieving the reductions of GHG emissions mandated for the group. The international community thus only has to devise how to monitor and sanction the group's behavior. The group members have the incentive to monitor and sanction the behavior within the group, since they would otherwise be held jointly responsible by the other groups. The incentives for the individual group members to live up to their commitments would therefore likely increase. Smaller groups can furthermore devise rules that work for them and their particular local conditions. Though on a much smaller scale, micro-financing works in a way

[45] It is noteworthy that though there are already blocs negotiating together on climate change (such as the bloc of small island states) our analysis is based on *formalized* groups of countries which jointly accept obligations.

similar to the way Ostrom's nested enterprises could be implemented on a global level. The business model of micro-financing has been successful with extraordinary high rates of repayment motivated by the associated incentive structures (Sachs, J., 2008, p.305). [46]

There are several reasons why dividing the international community into smaller, more homogenous groups might be beneficial. Large groups slow down decision-making processes and are more at risk for suboptimal provisions of the public good (Olson, M., 1965; 1982). It is also easier to sustain cooperation if the group is smaller. These characteristics have implications in both the first and second rounds of negotiations. In the second round, i.e. within the groups, it is also relevant that it is easier to provide the public goods if there is a higher degree of homogeneity in the group, which usually entails a larger sense of community and trust (Alesina, A., & La Ferrara, E., 2002). Within the group, there is a likelihood of less asymmetry in information. It is furthermore likely that the actors view the problem as well as their strategy sets in a similar way. These characteristics make coordination easier and more probable (Morrow, J., 1994; Schelling, T., 1960; Richards, D., 2001).

Dividing the international community into a few groups, whose group members then negotiate among themselves afterwards, also implies a two-stage negotiation process. Unless the total negotiation time is reduced and increased cuts in GHG emissions come out of the process, this leads to an increase in the amount of real resources spent on essentially unproductive activities (Bhagwati, J., 1982). A two-stage negotiation process also high-lights the need for a depoliticized decision-making process (see analysis of design principle 7) as there are more instances where political considerations could pervert the decisions. Regrettably, there is also the possibility that the demands of the groups in the first round of the negotiation process takes the form of a weakest-link games (Ellingsen, T., 2009c) whereby the GHG emissions reductions accepted by the groups are determined by the lowest accepted reduction of any individual member. If a group member in discussions regarding the first round accepts more than the others, it will be at risk of having to accept a larger share during the second round. Thus, the incentives are that no member will want to suggest accepting a larger reduction than that of the lowest within the group. A race to the bottom ensues in each group and the first round negotiations stalls.

[46] The repayment rates are in this case analogous to reductions of GHG emissions.

It is in this context interesting to study the between-group dynamics as well. While an inter-group chicken game describes a conflict wherein the groups believe a tie is a loss (Snidal, D., 1991), the inter-group assurance game better illustrates the situation if a tie is not seen as a loss (Bornstein, G., & Gilula, Z., 2003). Thus it appears that the latter game is more apt for describing the situation related to GHG emissions reductions, see chart 5 for a simplified illustration. With between-group communication, it is possible to reliably coordinate on the Pareto optimal outcome of within group provision (Bornstein, G., & Gilula, Z., 2003),[47] so the international community ought to reinforce the arenas for communication between groups regarding climate change on a level close to the decision-making.

Chart 5: Assurance game, a simplified illustration between-group relations regarding emissions

		Player B	
		emit	don't emit
Player A	emit	1 Nash 1	0 3
	don't emit	3 0	2 Pareto 2

There are many concerns related to an approach based on Ostrom's 'nested enterprises' which stem from the peculiarities of this issue. First of all, the groups would likely be based on geographic proximity as this is often a suitable proxy for facing the same conditions related to climate change. However, a lot of countries have tense relations with their neighbors which could preclude them from being able to build the trust necessary for the coordination. Ostrom's framework is as already noted largely based on a sense of community and trust.

Another challenge caused by the empirics of climate change and of preservation of the atmosphere, is the fact that the atmosphere is not divisible in any natural way, as opposed to the 'nested enterprises' studied by Ostrom (1990).[48] Groups would have to be 'humanly structured' and could therefore be at risk of losing their credibility. Agreeing on how to divide the international community into groups would, like so many aspects of in CPR preservation, turn into a second-order dilemma (Bates, R., 1988).

Another final empirically motivated concern is the fear of so called carbon leakage.[49] Though a legitimate concern, there are reasons why carbon leakage should not motivate a decision to refuse the 'nested enterprise' approach. The operational rules still solely concern the size of the reductions and not how these should actually be achieved. Countries will still be

[47] Bornstein and Gilula (2003) study a situation where the public good in essence have bad outcomes (such as armaments) and thus the Pareto optimal outcome is zero contribution in their illustration of the game. Their 'contribution' strategy is equivalent to our 'emit' strategy.
[48] Ostrom studied for instance irrigations systems that, though they were part of the same groundwater system, drew their water from separate rivers. This makes the separation of the metasystem into subsystems more logical.
[49] Carbon leakage is when polluting businesses move to locations where regulation is less strict, reducing the environmental benefits of regulation in their original location.

allowed to determine themselves the actual policies, thus retaining the power over potential carbon leakage.[50] In any case, recent studies have furthermore shown that actual carbon leakage is far less common than the political discourse may suggest (Barker, T., et al., 2007; Falkner, R., 2008, p. 23).

To conclude, we believe that this principle is transferable to the global scale to a large extent by devising a dual-level structure with nested enterprises for GHG emissions reductions. Dividing the international community into smaller, more homogenous groups could make coordination easier and provide for better contribution levels to the public good of emissions reductions, particularly if there is communication between the groups. A structure whereby the group members are jointly responsible for honoring their commitments can be recommended. This incentive structure could reduce the resource requirements for enforcement.

5. Discussion

Table 1 shows a brief summary of the findings from our analysis. The majority of Ostrom's design principles are to quite a large extent transferable, albeit with some modifications. We find that solely the third principle has a great difficulty in transferring to a global scale, due to the severe side-effects that its transfer would entail.

Jointly our findings show that by devising mechanisms to preserve the atmosphere based on the insights drawn, the international community should be able to overcome the problems that Ostrom found to be the major obstacles in CPR management. These problems, as elaborated upon in the discussion of the general applicability of Ostrom's framework, are also some of the most important problems in how the international community should organize itself to mitigate climate change. Implementing mechanisms based on transferable aspects from in particular design principles 1, 4 and 5 help to cope with free-riding, while mechanisms based on the insights drawn from these principles in addition to principle 3 also gives guidance on how to solve commitment problems. Principle 4 and, to some extent, principle 8 provide knowledge on how the international community could monitor individual compliance with a set of rules. Design principles 6 and 7 are essential in enabling actual implementation, as reality seldom works exactly the way that the theory dictates it should. Insights from principles 1, 2 and 8 are essential in arranging for the supply of new institutions, but do not give sufficient guidance on how to, on a concrete level, arrive at the operational rules, i.e. the reductions in GHG emissions per country.

[50] In some cases this authority lies with a region organization instead of an individual country, such as the case of the European Union.

Table 1: Transferability of and insights from design principles

Principle	Transferability	Insights
Principle 1	Moderate transferability	Difficulties of definition Striving for a complete agreement might have adverse side-effects Small groups more efficient, only a few countries jointly responsible for majority of global emissions, especially if coordination problems are abundant
Principle 2	Moderate transferability	Adaptable and flexible rules needed There should be a greater match between benefits received and burdens carried Private benefits for nations that embark upon a 'greener' path should be considered
Principle 3	Very low transferability	Consider asymmetries in power and in burden sharing There is a problem of procrastination Public opinion can play a significant role in policy making Commitment issues necessitate a solution where the global community "binds itself to the mast"
Principle 4 & 5	Moderate transferability	Commitments by nations can be organized into 3 major frameworks The effects of uncertainty can have a detrimental role to cooperation The problem of issue interdependence can diminish the legitimacy and credibility of the system
Principle 6	Transferable with minor modification	Strong institutions circumvent problem of strong nations exercising power to influence system Arenas alleviate problem of biases and subjective rationality An external research body can provide greater legitimacy to the system
Principle 7	Transferable	Highlights the importance of non-interference from governments Authority could be delegated to a fully independent expert committee
Principle 8	Moderate transferability, merits further research	Create a mutual support function by dividing the world into groups of nations Could improve likelihood of cooperation

As we have alluded to, there are furthermore several important ethical and moral issues of high dignity inherent in the issue of climate change mitigation. We will now briefly address some of them in relation to their economic effects. One of the main issues, though quite theoretic, is the question of the discounting rate used to calculate costs and benefits; how high should we value the future relative to the present? The philosophical question of whether we should even discount at all arises. Another crucial issue, and thus far the largest stumbling block in achieving international collective action on climate change, is contained in the determination of the principles used to divide the burden of reducing emissions. Should historic or contemporary emission be the base line? Should emissions be calculated on a per country or per capita basis?

Although we have mentioned such issues of burden sharing in discussing principles 1 and 2, Ostrom's (1990) framework regrettably does not give any concrete guidance.

Another insight from our analysis is that almost all the activities which the design principles entail are associated with second-order dilemmas, in for instance defining the resource and in negotiating the operational rules as well as in monitoring and sanctioning. Second-order dilemmas can cause impasse in negotiations and/or reduce the likelihood of other activities such as monitoring and sanctioning, which could cause efforts of solving the first-order dilemma to fail. It is therefore crucial for the international community to find ways of solving the second-order dilemmas.

It can be seen that the principles are essentially interlinked and have a fundamental impact on one another. An interesting question in this aspect is if they are also indispensible to one another. For example, in the global system monitoring empirically seems to be less of an issue and does not require significant contribution by the appropriators to its maintenance. Therefore, while that means sanctioning could be imposed without significant monitoring activities, it similarly means that arenas of conflict-resolution would be much more important in establishing legitimate sanctioning methods between countries. Furthermore, in studying the global institutional structure as of today we can see that certain prescriptions given by the principles are already present. For example there are examples of nested enterprises,[51] the institutions that have the power to monitor and distribute 'name and shame sanctions' are also present, particularly in the form of non-state actors such as NGOs.

Considering that design principle 3 is the sole design principle that was found to have low transferability, it is particularly important to evaluate whether this principle is indispensible. Ostrom's reason for including this principle was that such collective-choice mechanisms had on a local level been found to make operational rules more adapted to local conditions, had increased the perceived fairness inherent in the system and had established trust between users. The same objectives are however also addressed by the delegation of authority to a depoliticized expert group regarding for instance the formulation of operational rules, the outcome of transferring principle 7, and by the objective and fair conflict-resolution (principle 6). Thus, though design principle 3 could not be transferred due to its likely undesirable side-effects, Ostrom's intended outcomes of the original principle are to a large extent present in the transferrable set of principles.

[51] An example is that the European Union negotiates as one and then internally divides the GHG emissions reductions among its members.

One of the most detrimental issues taken from practice and recent global efforts for emissions reductions seem to derive from the very inherent differences between nations in regards to resource distribution. These asymmetries are highly amplified on the global level compared to the local level. There are further asymmetries in power, in information, in ability to coercion and in strategy constraints that can seem overwhelming or unsurpassable. In effect the question of burden sharing implied by design principle 2 has a major impact on the rest of the system. It is the inherent resource heterogeneity that could be seen to impact the agreement between nations on definitions, the methods of monitoring and sanctioning as well as the perception of right and wrong in the arenas for conflict-resolution. Taking this argument to an extreme, it could be maintained that without agreement on how to assimilate the system with these differences there would be major strains on the system.

A further insight we gathered was the significant amount of controversy offered by the literature, which has sometimes resulted in conflicting arguments during the analysis within the individual principles. There are sometimes conflicting elements which can yield different conclusions; for example in the analysis of principle 1 where the non-excludability characterization and the coordination aspect give conflicting insights for the optimal number of parties to the treaty. As far as possible we have tried to balance these insights. Similarly we would like to argue that this impacts the inter-principle analysis as well. There is a risk that such conflicts create overlapping as well as conflicting elements in the conclusions drawn from analysis of different principles. We have however not found any overarching conflicts but realize that this can become a significant issue in a more concrete implementation of the principles.

5.1. Uncertainty

We have throughout this paper maintained the importance of uncertainty. There are three main types of uncertainty present within different aspects of the climate debate; the uncertainty associated with not knowing the pay-offs of different types of action, the difficulty with which the international community can adapt to fluctuations as well as the difficulty in providing complete information with monitoring. Considering monitoring we have seen, from the analysis of design principles 4, 5 and 6, that the lack of perfect information is not detrimental to sustaining long-term cooperation. This is mainly due to the inherent nature of global climate negotiation where the discussion is centered on the key issues instead of the possible occurrence of an infraction by a certain party.

As regards the uncertainty associated with the different pay-offs of certain strategies we maintain that this is a significant consideration but not as important as it has been in the past. It

has now been established to a very high extent that climate change is a result of GHG emissions due to human activity and that the process can be mitigated given the right initiatives. It can however still be seen that certain players try to diminish the importance or urgency of the problem and act in accordance with self-serving biases on the issue. This can reduce the certainty with which other players can form their expectations of future strategies of their negotiating partners.

Instead we argue that the uncertainty caused by fluctuations on the global arena can become a significant consideration, which in its most severe form can cause cooperation to break down in periods of low resource productivity (Ternström, I., 2001). Despite the fact that there are significant and quite irregular fluctuations in climate patterns, atmospheric concentration of GHGs only have minor, well-known seasonal fluctuations. Thus it would be appropriate for the international community to put a larger emphasis on the actual GHG concentration rather than on the effects on the climate. Similarly, significant fluctuations in both the political and economic situations of nations such as ideology or economic cycles can impact the propensity and willingness to contribute to climate preservation. This might ultimately impose a heavy burden on climate initiatives.

5.2. Legitimacy, Credibility, Commitment

Finally, there are as we see it three factors that are of great importance in achieving a coordinated global system for the preservation of the commons; legitimacy, credibility and commitment. Ensuring that there will be credible commitment to the system and the operational rules is a crucial part to establishing a global regime working towards the same goal, i.e. ensuring adequate contribution to the public good of a stabilized climate. Commitment is achieved by the right incentive structure and the presence of monitoring and sanctioning activities. All principles do in fact contribute to establishing commitment, often in the manner of quasi-voluntary compliance (Levi, M., 1988).[52]

It is essential for long-term cooperation within any system that appropriators consider it legitimate. Legitimacy is often linked to a sense of community; it both depends on and prompts the proliferation of social norms such as trust and reciprocity. In our analysis, this is in particular contained in the fact that appropriators should be left to craft their own rules free from political interference (design principle 7) and in the necessity for conflict-resolution mechanisms that are considered fair (design principle 6).

[52] See footnote 20.

Credibility on the other hand is mainly a component in the enforcement of certain promises and threats. There must be congruence between the promise or threat and actual enforcement of the rules set up in design principle 2, the ability to exercise modification of the rules in principle 3, the enforcement of monitoring and sanctioning in principles 4 and 5, and the objective resolutions of conflict in principle 6. Without consistency in this manner and the careful adherence to social norms it would be difficult to maintain the system in the long-run.

It is important to note that all the above factors have to be present and consistently maintained for the perseverance of a well functioning global system. They are also inherently interlinked since the lack of one impacts the strength of the other two.

5.3. Potential Challenges Addressed

Within our analysis there are certain points that could possibly be challenged. We would like to address the three criticisms that we find mostly likely. Our thesis does not challenge the original principles as formulated by Ostrom. These principles are however generally accepted and praised by the global academic community by now. Another potential criticism would be concerning some of the simplifications that we have made, which could be disputed. These have mainly been made due to the fact that a full consideration of all the global forces, including causes and consequences of actions, would have created "descriptive complexity and theoretical anarchy" (Keohane, R., 1982, p.20). Referring back to the initial analysis, we could in this context present the simplification of treating states as individuals. Finally, our analysis could be criticized for not considering issues related to agency problems (Jensen, M., & Meckling, W., 1976). Considering the issues related to implementation in many countries would also have been beyond the scope of this paper. Despite these potential challenges we would like to maintain that our results are not without validity.

6. Conclusion

In this thesis we have attempted to acquire insight on how to achieve a global system for preserving the atmosphere, more specifically how to stabilize its concentration of GHG, in order to mitigate climate change. At first we established that the atmosphere can be treated as a CPR, provided that the international community set a threshold concentration of GHGs which cannot be surpassed. After verifying that the atmosphere as a CPR satisfies the underlying assumptions of Ostrom's (1990) framework, we have furthermore found that the eight design principles which according to Ostrom characterize successful CPR systems to a large extent can be transferred to the global scale. Additionally, our analysis has shed some light on suitable ways for the

international community to structure the actual mechanisms involved in the resource management system.

Considering the importance and the scale of the challenge, we expect that there will be many more studies regarding the economics of anthropogenic climate change. We hope that the related collective action queries are given particular attention. There are many interesting topics that have come up during our analysis that merit further study. We especially encourage deeper scholarly work into the feasibility and structure of a 'nested enterprises' approach, focusing on issues such as within-group and between-group dynamics, how to assign countries to different groups as well as on issues of coordination and communication between groups. We also believe that it is of outmost importance that more concrete evaluations of different ways of implementing the theoretic recommendations given by studies such as this one are examined.

The urgency of the issue has to be stressed, but "although the prospect of reaching a global agreement on such a complex issue, which involves a resource (the atmosphere) shared by every nation on the planet and strikes at the very core of our global economic system, is daunting, it is not impossible. Climate change is certainly a solvable problem" (Sachs, J., 2008, p.112).

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