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Exogenous Change in the Regeneration of a Common Pool Resource and its Effect on Cooperation and Efficiency

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Abstract

The natural sciences explain how climate change affects the provision of ecosystem services. Behavioral economists have studied the effects of institutions and social interaction on cooperation, to prevent over-exploitation of common pool resources. Bridging both disciplines, this paper investigates two intrinsic characteristics of climate change and their effect on resource management. Climate change irreversibly disrupts the balance of ecosystems, often causing a continuous decline in resource growth. Abrupt and extreme weather phenomena are also observed, temporarily affecting resource size. Contrasting these effects with stable resource development, we investigate whether resource users respond differently in terms of cooperation and extraction efficiency. By means of a dynamic common pool resource request game with university students, we found differences between the treatments. A continuous decline was associated with falling growth-stock ratios, which increased resource depletion toward the end of the game. A drastic shock affected cooperation negatively, but only temporarily, an effect we attribute to marginal cheating hidden by environmental volatility. Although inconclusive of any long-lasting significant effects on cooperation or efficiency, we contribute with an understanding of the temporary effects of exogenous shocks, for the first time with free communication and uncertainty.

Keywords: common pool resources, cooperation and efficiency, new generation of experiments, climate change, uncertainty, exogenous shocks.

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A final thanks for the love and support from our friends and families.

Give a man a fish,
and you feed him for a day.
Teach a man to fish,
and you're left with a social dilemma.

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1 Introduction

Since pre-industrial ages, global surface temperatures have risen by 0.9 degrees Celsius (NASA 2018), an increase which 97 percent of climate change experts attribute to human activities (Cook et al. 2013). The impact of the environmental consequences that will follow is uncertain, but predicted to cause crises as severe as the world wars and depressions of the twentieth century (Sala 2000). This indicates that our geological time age has shifted from the Holocene to the Anthropocene (Zalasiewicz et al. 2008). We are experiencing one of the fastest mass extinctions in geological history, expected to eradicate 15–40 percent of all living species by 2050 (Thomas 2013). Combined with rapid population growth, this mass extinction brings attention to common pool resource management. Common pool resources are non-excludable and rivalrous (Ostrom and Ostrom 1977). Fish is such a resource that lives in a complex and adaptive marine ecosystem, experiencing high levels of uncertainty by default. Ecosystem services are natural processes that benefit humans. Fish regeneration is an example of a marine ecosystem service where climate change alters both growth and size. One effect of climate change is ocean acidification, that irreversibly disrupts the ecosystem, resulting in a continuous decline in resource growth (Stern 2006). Another observed effect is increasing variation and intensity of weather events, triggering abrupt and extreme phenomena that drastically impact stock sizes (Francis and Hengeveld 1998).

The tragedy of the commons is a theoretical explanation to anachronistic overexploitation of common pool resources (Hardin 1968). In light of this, we have chosen to study the effects of exogenously driven changes to the resource dynamics (regeneration and size) of common pool resources on behavioral responses. Specifically, our research question inquires into the effects on cooperation and efficiency. As such, the purpose of our study is to isolate any possible intrinsic effects of climate change that affect resource management, in a real-world experimental setting. We decided to test how a continuous decline and a drastic shock in the regeneration and size of a common pool resource differs from a scenario with stable resource development. We have tested this in a framed lab experiment with university students, building onto the design developed by Schill, Lindahl, and Crépin (2015) and Lindahl, Crépin, and Schill (2016). In our experiment, a common pool resource request game was played, where four players made individual harvest decisions based on a shared pool of real-value resources. The game was played for a finite number of rounds, between each of which growth differed across stock size intervals. To keep the stock size in the optimal interval, with maximum growth, the participants were free (but not forced) to communicate and make agreements about (still anonymous) catch decisions. Our contribution to this established methodology includes the introduction of uncertainty, volatility, delayed feedback and exogenous shocks to the growth. Using an identical design setting, we only varied the regeneration across the three treatments. The first treatment (Uncertainty) had a volatile, yet stable development of the resource growth, while the second (Continuous), a continuous decline in the growth, and the third (Drastic) a temporary, abrupt and negative shock to the size of the common resource. In all three treatments there was an additional source of uncertainty through delayed information on regeneration. We observed individual and group behavior to quantify the effect on cooperation and efficiency.

The experimental methodology has been selected to isolate treatment-specific effects by providing a clear counterfactual. In real-world systems, both social and ecological contexts differ, which complicates the identification of the causal mechanism of cooperation and efficiency. Incorporating insights from institutional arrangements and cognitive psychology, the experimental observations find predictors of behavior in complex adaptive systems, unexplained by rational actor theory (The Committee for the Prize in Economic Sciences in Memory of Alfred Nobel 2017). Subsequently, the experiment can be taken to the field with samples matching resource-managing populations, to further our understanding of common pool resource management. While our experimental findings solely explain student interaction in a common pool resource request game, once taken to the field and if shown to correspond with the real world, these insights could contribute to the understanding of universal behavioral factors that drive climate change. The causal variable of climate change itself is a tragedy of the commons i.e. the atmosphere's destruction capacity is a non-excludable and rivalrous common good that is over-exploited by humans through massive emissions of greenhouse gases. Both the causal variable, and the direct consequence, of common pool resource over-exploitation, can therefore be avoided with a better understanding of common good management. Our experiment aims to contribute to this understanding, but cannot alone provide any inference outside its intended limitation of scope.

The plethora of academic literature we aim to contribute to is diverse and includes several ecological issues that affect cooperation in social dilemmas. Experimental outcomes vary if performed in the field or in a lab with student samples (Cárdenas 2000). Communication has in various studies shown to have a positive impact on cooperation and thereby efficiency (Ostrom 2006). The same factors have also been positively affected by locally shaped agreements in contrast to externally imposed regulations (Pretty 2003). Environmental uncertainty in combination with strategic uncertainty has shown to threaten the long-term survival of ecosystems (Maas et al. 2017). Another important issue is trust and path dependency, where building trust from the start has shown to be important (Baggio et al. 2015).

Section 2 provides a guide through previous experimental literature in common pool resource dilemmas of social and ecological variables that affect cooperation.

2 Theoretical background

Game theoretic derivations of inefficient equilibria motivate rigorous social dilemma analysis, a reaction to the unrealistic assumptions of human nature in classical economics. Through the conceptualization of psychological insights, behavioral economists look into alternative factors to explain these inefficiencies. Studying human-nature interactions has led to the emergence of a new generation of experiments. It is in this realm of the new generation of experiments that we aim to fill a research gap, by testing local adaptation to exogenously driven changes in the environmental conditions regulating the provision of ecosystem services. Mimicking the real world, with uncertain growth and unregulated communication, we aim to provide new insights into human interaction when facing simulated climate change-driven crises.

2.1 Game theory and the tragedy of the commons

The prisoner's dilemma is a game with two or more players, where there is a dominant strategy for each player not to cooperate, which leads to an inefficient equilibrium outcome. For example, if all countries cooperate with strict legislation to protect the atmosphere from the emission of greenhouse gases, the whole world would benefit from a stable climate. If deviation is associated with private benefits (such as higher GDP growth), each actor has incentives to unilaterally change from a cooperative to a non-cooperative strategy and start emitting. Moreover, if no country cooperates to limit emissions, and if it is costly to do so, there is no incentives for any country to unilaterally change to a cooperative strategy. The only equilibrium, or state where there is no incentive for any country to change strategy unilaterally, is a non-cooperative one, where all countries emit greenhouse gases. This is an inefficient equilibrium, since all countries would be better off cooperating. The same reasoning can be applied to overfishing. If all fisheries agree on how much to fish, a steady stock could be sustained for future generations.

The prisoner's dilemma has both a static (one-shot) and a repeated dimension. In the context of utility-maximizing rational actors, when approaching the last round in a game with a finite number of rounds, every player will cheat (as in a classic one-period prisoner's dilemma). This is common knowledge and there is nothing that can change this outcome, therefore no one will cooperate in the second last round since there is nothing to signal. Following the chain-store paradox using backwards induction (where there is no incentive to cooperate in the last, second last, third last round and so on), a known end in a near future creates a non-cooperative equilibrium (Fudenberg and Tirole 1996). This is however not necessarily true for an infinite game, when the end is unknown and expected to be far in the future. In an infinitely repeated prisoner's dilemma, if players are patient enough, cooperation can be sustained through so called grim (or trigger) strategy. In this strategy a player cooperates as long the other players cooperate, otherwise the player will defect for the remainder of the game. If the end of the game is unknown, the optimal strategy is determined by an individual's estimated probability that the game will end soon. Once a player expects the game to end soon, the maximum defection strategy generates a higher payoff than that of following through on cooperative agreements, and thus that actor will, following a utility-maximizing strategy, defect immediately.

While this theory is mathematically convincing it is incomplete, since efficient long-lasting cooperative agreements prevail in the real world. With the assumptions of utility-maximizing rational actors shown unrealistic, we turn to behavioral insights for solutions to the prisoner's dilemma.

2.2 Institutional arrangements for common dilemmas

Ostrom's *Governing the Commons* emphasizes the importance of norms and social interactions in the protection of common pool resources (Larsson, Bratt, and Sandahl 2012). Based on several case studies, Ostrom defined eight social conditions for sustainable resource extraction: 1) presence of clear boundary rules, 2) rules that restrict the harvesting of resource, 3) individuals affected by resource regime participate in the rule-making process, 4) partakers of resource select their own monitors, 5) graduated sanctions for rule violations, 6) access to arenas to resolve conflicts, 7) recognition of right to organize and 8) nested organizations (Ostrom 1990). With these insights, managing the commons shifts from a binary policy decision of privatization or strict government control, to an understanding of group configurations and human interactions where coordination yields more desirable outcomes in social dilemmas.

The main advantage of performing controlled lab experiments is that they provide a clear counterfactual to identify relevant variables, making them more common now than in the past in the social sciences (Poteete, Janssen, and Ostrom 2010). Experiments also provide valuable psychological insights in common pool resource games (Kopelman, Weber, and Messick 2002), especially when adopting a multi-method approach where new theoretical predictions are empirically evaluated (Ostrom 2006). Lab experiments allow for collection of controlled and replicable data, useful for isolating phenomena in noisy surroundings (List and Price 2013). There is also an increased tendency to take lab experiments to the field to make real resource users interact in the games (Cárdenas 2000). Several studies build onto Ostrom's principles to increase the understanding of what drives cooperation in common pool resource management. The third principle, regarding the importance of decentralized decision making, was confirmed by Pretty (2003) in an investigation of the hundreds of thousands of local initiatives formed to protect the commons around the world. Pretty found that indigenous groups following local initiatives often managed their common pool resources successfully, even adapting to changes in environmental contexts. Pretty also found that central policy making could be harmful and hard to implement with successful results, shedding light on the importance of local agreements. This view was confirmed by a framed field experiment with Colombian fishermen, also on common pool resources, by Pilar Moreno-Sánchez and Maldonado (2010) that found local co-management to both prevent over extraction and increase overall efficiency.

The importance of locally shaped agreements is the main insight from an institutional perspective of common resource management. Within a given set of institutions, cognitive psychology provides additional insights to factors driving cooperation.

2.3 A framework based on nine psychological insights

In her later publication, *The Drama of the Commons*, Ostrom et al. (2002) identified nine variables that affect cooperation in common dilemmas. Each based on experimental psychological research, the variables (social motives, gender, payoff structure, uncertainty, power and status, group size, communication, causes, frames) have shown to affect the outcome of cooperation in previous academic literature. Studies relevant to our experimental setting will now be presented for each variable.

1) Social motives are individual traits, classified as either proself or prosocial. Proself traits describe individualist players that aim to maximize their own profits, and competitive players that aim to maximize relative profits. Prosocial traits describe cooperative players that aim to maximize joint payoffs, and altruistic players that aim to maximize others' payoffs. While prosocial players consider cooperation as moral, proself players consider it ineffective.

Kimbrough and Vostroknutov (2015) found that individual traits also significantly affect cooperation. Before performing a standard common pool resource game, they divided players into groups based on each participants' tendency to follow rules. The separation was done by having each player play a sub-game in which they could choose to stop for a simulated red light or continue for a pecuniary reward. Groups with more rule-followers, suggestively prosocial players, tended to cooperate better.

2) The literature on gender differences and common dilemmas is sparse and at times contradictory. While Brown Kruse and Hummels (1993) found that all-men groups contribute more to a public good than all-women groups, Nowell and Tinkler (1994) found the opposite to be true, and all-female groups to be more cooperative than any other group constellation. Stockard, Kragt, and Dodge (2008) found that in mixed groups, women were more willing to contribute to the public good.

3) Payoff structure deals with the social rewards that can overcome monetary punishments of cooperation (changing the game type to a deadlock). Since threats and side payments were forbidden during and after our experiment, there was no

method for the participants to change the incentive scheme and transform the game to a deadlock. However, Fehr and Gachter (2000) found that players just meeting before and after the game increased cooperation.

4) Uncertainty has shown to significantly decrease cooperation and often lead to complete resource depletion. One type of uncertainty relates to stock sizes, where proself behavior is motivated by players expecting the stock to be larger, legitimizing immoral actions. Several cases of uncertainty pertain to social ecological interactions in the new generation of experiments see Section 2.4.

5) Power and status affects a group by legitimizing actions if performed by high status individuals, influencing the collective action in a group. Perez et al. (2015) studied the effects of group composition on cooperation. They studied communication between resource users in a lab experiment simulating an irrigation system where the participants communicated through text messages during the game. They found that no leadership role was sufficient to reach efficient investments, but that a combination of certain roles increased the chance of avoiding under-provision. This suggests that though power structures matter for group outcomes, it cannot solely be attributed to simple leadership roles.

6) Group size is negatively correlated with cooperation and one major explanation is the concept of self-efficacy. If the group is smaller, an individual is in higher control of the resource, and since individuals on average believe themselves to be more competent managing a resource, they tend to trust more the resource survival.

7) Communication has shown in many studies to increase cooperation and the main explanations regarding group identity and commitments to cooperate. Both conventional and new generation experiments have confirmed the importance of communication for sustainable resource management.

One study by Kreitmair (2015) shows the role of common knowledge and information asymmetries for cooperation. If each resource user's extraction was known to the other participants, the cooperation would increase significantly. They also showed that voluntarily shared information created a long-term sustainable resource management. Balliet (2010) further found that communication face to face was more efficient than text message communication. Groups that could communicate face to face managed the common pool resource much more effectively than other groups. Not only intra-generational communication can help sustain the resource, also inter-generational communication. Groups that had the chance to communicate with groups that had already played the game cooperated better and handle the resource more effectively (Hillis and Lubell 2015).

8) The *causes* of the dynamics and changes may also affect cooperation. Talarowski (1992) tested in Californian drought seasons how participants would react if a poor performance was exogenously driven or caused by poor cooperation. It turned out that crises caused by greed generated a negative shock to cooperation,

and crises caused by natural phenomena sustained similar levels of cooperation. This highlights the importance of path-dependency and the importance to build trust in an early stage of a commons dilemma. The same conclusion was drawn by Poteete, Janssen, and Ostrom (2010) when testing path dependency in lab experiments, if a group manages to start cooperatively, the same strategy is often followed throughout the experiment.

9) Frames are context-contingent presentations of situations. The most cited work on frames is prospect theory by Kahneman and Twersky (1979) showing that different perceptions of gains and losses significantly impact economic decisions (Ostrom et al. 2002). Building onto this, Kahneman (2011) found that loss-stricken individuals have a higher propensity to take risk in hope to break-even, susceptible to the sunk cost fallacy.

One drawback found in several of the aforementioned experiments is that they fail to incorporate the interconnection between ecology and society. Ecological conditions and variations increase the complexity that is faced by resource users. This complexity can by itself affect cooperation and with the purpose to better mimic the field a new generation of experiments has emerged.

2.4 The new generation of experiments of social ecological interactions

The new generation of experiments recognizes ecological conditions in economic experiments and aims to test their effect on communication, cooperation, efficiency, and other variables crucial for sustainable development of scarce resources. To exemplify, the effect of over-exploitation is interpreted differently from under-exploitation, despite the same effect on efficiency, since the long-term survival of a resource being over-exploited substantially differs from one being under-exploited. There is no standard design for the new generation of experiments, or a clear boundary that separates them from old type experiments. However, the common denominator is that there are ecological aspects present in the field incorporated in the experiment. Below follows a summary of relevant literature from the new generation of experiments relevant for the scope of our research.

Walker and Gardner (1990) performed a new generation risk-shifting experiment where the participants could choose an amount to invest in a common good that increased in value. If too much was invested, passing a certain threshold, the probability of the game ending increased significantly. They found higher investments than predicted by conventional economic theory which led to inefficiently many collapses of the game. The threshold was used to simulate that if too much of a common good is used, the risk of the ecosystem to collapse rapidly increases, an ecological feature that is not captured in standard cooperation games focused on social and institutional factors.

Baggio et al. (2015) studied environmental risk in irrigation systems. They created asymmetries by endowing a disadvantage to those further down the system, which increased the importance of trust. The exact payoff for the players was not only dependent on how much they collectively invested, but also on how much it rained. The exogenous rain levels were probabilistically determined and the main insight was that the environmental variability had little effect on individuals' investment decisions. The importance of path dependency was underscored. If a group started out cooperatively, they received positive feedback from the group that built trust and increased the chance of sustaining the resource. This was confirmed by McAllister et al. (2011) who studied how reciprocity interacts with variability and uncertainty. If the uncertainty was introduced after a few rounds, trust had already been established and the variability had little effect on the outcome, however, if the environment was uncertain from the start, groups would tend not to build the necessary trust to sustain cooperation.

While the above experiments regard stochastic outcomes, other studies have investigated cooperation in uncertain environments. Gustafsson, Biel, and Gärling (1999) conducted a common pool resource game where the stock size was uncertain. They contrasted different sizes of the optimal interval and found that with greater intervals, or uncertainty, higher levels of over-exploitation followed. They recalled the outcome-desirable bias, or optimism, as the theoretical principle that lead to the inefficient outcome. They found this to be true for individuals playing individually and groups with real or imaginary unfamiliar participants. On the topic of uncertainty, Maas et al. (2017) found that the combination of strategic uncertainty (of how other players will act) and environmental uncertainty (of how the resource will grow) was enough to lead to a collapse of the ecosystem. The risk for total depletion had increased with the uncertainty for which interval to aim for which led to lost faith in ecosystem survival. They argued that there were parallels to the climate change negotiations that have often collapsed due to lost faith in such uncertain ecosystems. Similar arguments have been proposed by Gangadharan and Nemes (2009), who also found ecosystems to collapse with the combination of strategic and environmental uncertainty. Hine and Gifford (1996) extended these results, even though they did not find complete depletion, to also include uncertain regeneration. They found that both uncertain stock sizes and regeneration (and the combination of both) decreased efficiency.

The role of communication has also proven important for new generational experiments. In a common pool resource experiment by Bell et al. (2015) it was necessary, but not sufficient to avoid over-exploitation in an irrigation system context. Many studies have however been performed with restrictions on communication. In a no communication setting, Osés-Eraso, Udina, and Viladrich-Grau (2008) investigated the effect of scarcity on investments in a public good. With scarcity, participants tended to over-exploit less and follow the optimal strategy over time.

Cherry, Lance Howe, and Murphy (2015) simulated environmental shocks in the arctic that often lead to large asymmetries between actors and over time. Bringing this context to the lab, they found that participants tended to cooperate more than predicted by theory if there was a system for voluntary risk-pooling. This brings back the attention to local management of resources. Knapp and Murphy (2010) tested if local rights based management was more efficient than externally imposed regulations and found so to be true. They also found that heterogeneity of fishermen improved cooperation in the game where the participants could choose between investing in a common (risky) and a private (safe) resource. The local variations are also an important aspect in predicting cooperation. Taking a lab experiment to the fields of Thailand and Columbia, Castillo et al. (2011) found substantial differences in cooperation between different fishing villages where different fishing techniques were used. They also confirm the hypothesis that trust in a remedy increases if it is imposed by the local community, in comparison to if it is imposed externally.

The above studies include both common pool resource games and public good games. The three following studies are following a similar design with a common pool request game, played over a number of rounds, where players individually request how much fish to catch from a common pool. They all allow for free communication and have served as a basis point for the experimental design that we have adopted.

Lindahl, Crépin, and Schill (2016) used a logistic function for the regeneration-rate intervals, where the growth was highest for medium-high stock sizes, with a critical threshold below the optimal level in which the growth abruptly dropped. They tested if the existence of this threshold increased cooperation. They found that the threshold groups cooperated more, over-exploited less and were more efficient since they communicate more. However, they did not find that cooperative groups were more efficient than non-cooperative groups. The main insight from their experiment is that if information about regime shift risk is available, economic agents cooperate more to avoid the catastrophic scenario. This experiment was then taken to the fields of Thailand by Lindahl and Jarungrattanapong (2018) using a simplified resource dynamics and found that the threshold increased cooperation. Morevoer, they found that socio-economic variables seem to have influenced behavior, such as age, birth place and presence of side incomes.

Schill, Lindahl, and Crépin (2015) took this design even further by introducing risk. Two versions of a similar game were first performed with university students and then with Colombian fishermen (Schill 2017). The players were faced with a logistic function, but with a known risk that a regime shift could impose a threshold. They did not find that any significant difference in terms of exploiting beyond the critical threshold. However, they did find that groups facing a threshold with certainty or with high probability were more efficient. Their study supports the thesis that information about potential regime shifts should be made available, even though they are not certain to occur. An interesting addition to this study is that cooperative groups were not found to be significantly more efficient or less over-exploitative than non-cooperative groups.

The psychologically driven group response to simulated scenarios of real-world dilemmas, such as climate change, has to our knowledge never been studied in the context of free communication and uncertain growth. On the one hand, local adaptation has proven effective in the past, especially in the presence of free communication. On the other hand, uncertainty and scarcity has caused trust and ecosystems to collapse in the past. How a group responds to exogenous shocks or declines in these complex, but somewhat realistic, settings, is the research gap that this study aims to fill.

3 Research question

In the context of a social dilemma of common pool resources with free communication, and uncertainty, we pose the following research question:

How do exogenously driven changes in the resource dynamics of a common pool resource affect cooperation and efficiency?

To clarify this overarching research question, we have divided it into the three following specific sub-questions:

1. How does declining resource regeneration affect cooperation and efficiency?
2. How does a drastic exogenous shock to the size of a common pool resource affect cooperation and efficiency?
3. How does a drastic exogenous shock to the size of a common pool resource contrast to a declining resource regeneration affect cooperation and efficiency?

4 Introducing the game

The experiment designed to answer the research question included three treatments with different regeneration over time. This section describes the design, analysis and considerations for the game.

4.1 Experiment design

The game was played for a number of rounds and the four players shared a common resource that reproduced between each new round. The experiment leader explained the growth to the players, both conceptually and through various examples, referring to actual field conditions. For example, the optimal growth interval was explained with the motivation that "[at this level] there are not too many fish that they compete for food, but still enough for them to easily find mating partners and reproduce." The underlying purpose of these explanations was to immerse the participants into a real-world scenario, behaving like fishermen rather than students.

Every game started with 50 fish in the sea. Each participant could harvest between 0 and 15 fish in every round, a realistic constraint as a single small-scale fisheries cannot deplete the sea in just one year. The participants would always know the fish stock size, which developed according to Identity 1 below:

$$stock_{n+1} = stock_n - catch_n + growth_n \tag{1}$$

However, the growth for a given round $growth_n$ was only revealed to the participants after a three-round delay. Therefore, only in round $n + 3$ could participants calculate the group catch $catch_n$ and identify possible cheating (which we define as defecting from an agreement). Since the growth varied between rounds, the players could only distinguish between environmental changes and group harvest decisions three rounds after they made their decisions. For pedagogical reasons, each round was assigned a year and the game started in 2018 (with initial published growth from 2015). Every round, the growth also varied between different intervals of fish stock, see Table 1. For low or high stock sizes, the growth was lower than in the middle (optimal) interval. The participants were informed about the rationale behind these variations (too few fish have a hard time reproducing, too many fish compete for food) and could comprehend the relationship between the intervals. All participants were made aware that the growth could be either positive, and in that case most positive in the optimal interval, or negative, and in that case least negative in the optimal interval. The intervals were the same for all treatments.

Table 1: Example of regeneration per treatment in 2015

Stock Size Interval	Uncertainty	Continuous	Drastic
46-50	0	0	0
35-45	4	7	5
20-34	8	15	10
5-19	4	7	5
1-4	0	0	0

Regeneration rates for all treatments in year 2015 (game started with growth from year 2018 with growth information from 2015)

The only difference between the three treatments was the development of growth. For the Uncertainty treatment the growth, while fluctuating, remained stable over time. The exact resource growth is presented in Table 2.

Table 2: Uncertainty regeneration

Interval/Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
46-50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35-45	4	5	3	3	5	3	3	4	4	6	4	3	4	5	3
20-34	8	9	6	7	9	6	5	8	8	11	8	6	7	9	7
5-19	4	5	3	3	5	3	3	4	4	6	4	3	4	5	3
1-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Regeneration rates in the Uncertainty treatment for all intervals in all rounds (game started with growth from year 2018 with growth information from 2015)

For the continuous treatment the growth continuously declined over time, see Table 3.

Table 3: Continuous regeneration

Interval/Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
46-50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35-45	7	7	7	7	6	5	5	4	4	3	3	3	3	2	2
20-34	15	15	14	13	11	9	9	8	7	7	6	5	5	4	4
5-19	7	7	7	7	6	5	5	4	4	3	3	3	3	2	2
1-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Regeneration rates in the Continuous treatment for all intervals in all rounds (game started with growth from year 2018 with growth information from 2015)

The Drastic treatment included a drastic shock in round 2022-2023 with negative followed by zero growth. This is the only treatment where the relationship between the intervals significantly changed (during the periods of the shock), as shown in Table 4.

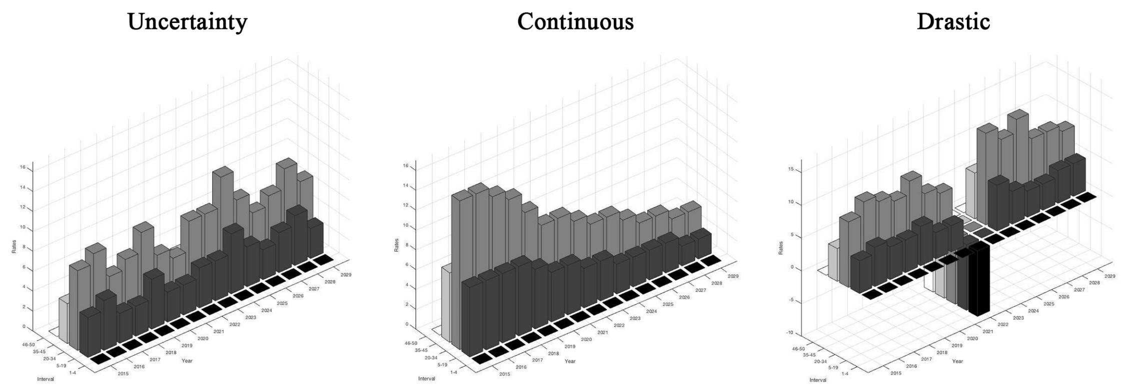
Table 4: Drastic regeneration

Interval/Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
46-50	0	0	0	0	0	0	0	-10	0	0	0	0	0	0	0
35-45	5	6	5	5	6	4	4	-10	0	7	5	4	4	5	5
20-34	10	12	10	11	12	9	8	-10	0	14	12	14	10	10	9
5-19	5	6	5	5	6	4	4	-10	0	7	5	4	4	5	5
1-4	0	0	0	0	0	0	0	-10	0	0	0	0	0	0	0

Regeneration rates in the Drastic treatment for all intervals in all rounds (game started with growth from year 2018 with growth information from 2015)

The growth for all treatments are illustrated in Figure 1 below. Symmetrical across intervals, the graphical representation brings attention to the, on average twice as high, growth in the optimal interval compared to the adjacent intervals, emphasizing the growth to be gained by keeping the stock size in the optimal growth interval. Furthermore the illustration brings out growth trends in the three scenarios. The Uncertainty treatment is characterized by a random growth development deviating around a mean, the Continuous treatment by continuously declining growth, and the Drastic treatment by a random development followed by an abrupt and temporary drop in the growth.

Figure 1: Resource Regeneration

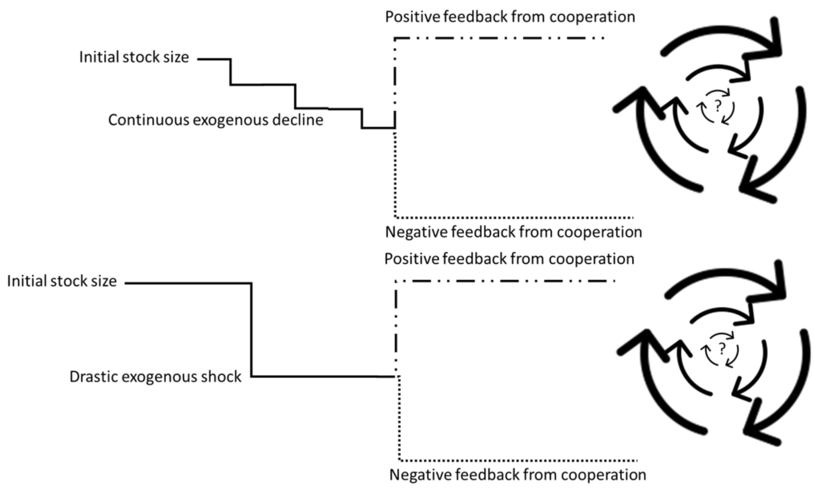


Own illustration of growth rates for all three treatments over all intervals in all years.

4.2 Motivations for the design

There is an interdependence between social and ecological factors that determine common pool resource supply, shown in Figure 2 below. Ecosystem services react to human extraction, while human extraction is based on the provision of ecosystem services. Our experiment sought to test if negative exogenous shocks to the provision of ecosystem services could result in an ecosystem collapse, or if cooperative responses can break the negative spiral. The results of which is primarily determined by human-induced actions. While individual fishermen are unable to control climate change, they can choose to adapt to the environmental changes to sustain the resource.

Figure 2: Feedback from cooperation



Own illustration of the interplay between human behavior and natural ecosystems for sustainable resource development.

To test this interchangeability we decided to conduct laboratory experiments. Even though both continuous declines and drastic shocks to the regeneration of common pool resources can be found in the field, comparing their effects on cooperation is close to impossible due to variations in both social and ecological factors. The decision to conduct the experiment with a student sample was primarily motivated by economic constraints, however, the instructions and game design was built on instructions used by Lindahl and Jarungrattanapong (2018) in a framed field experiment. Congruent instruction facilitate future replication of the experiment design in the field.

4.2.1 Rationale for game features

The overall purpose of our research design was to mimic real-world ecological settings and translate them into viable characteristics of a request game. As such, the translation of climate change-driven scenarios into game features as well as the outer circumstances of scenario testing will now be motivated.

Marine ecosystems are complex and therefore predictions will always be uncertain. Climate change is expected to increase growth variability between species, but not necessarily within species. Therefore, unpredictable variations in stock sizes serve as a non-climate related base property, which we refer to as Uncertainty (Brander 2007).

One of the major consequences of climate change is rising sea temperatures, changing natural habitats for marine species and causing displacement of fish species that are unable to adapt. Species-specific effects differ significantly, some stocks will increase while others decrease (Ficke, Myrick, and Hansen 2007). Overall marine ecosystem productivity is predicted to decline the most in tropical and subtropical regions (Daw et al. 2009). Furthermore, the variation between regions will increase. Due to fish migration the tropical regions will suffer a decrease while higher latitude regions may benefit from a higher catch potential (Cheung et al. 2010). More diseases, algal blooms and invasive species are predicted to negatively affect fish regeneration in marine and freshwater systems (Allison et al. 2009). Another climate-related factor driving a decline in fish regeneration is coral bleaching. Since coral reefs closely interact with fishes, the species most dependent on shelter provided by the reefs suffer the most (Roessig et al. 2004). These phenomena are underlying examples of the Continuous treatment design.

Climate change also causes differential warming on land and sea, resulting in more intense weather phenomena with devastating consequences, such as El Niño (Francis and Hengeveld 1998). Catastrophic weather events have shown to cause intense fish evacuation, with temporary fish loss as a consequence (Bailey and Secor 2016). Weather events, climate change-driven or not, are inspiration for the Drastic treatment.

It is relevant to study the different types of exogenous changes to determine which principles guide cooperative behavior in a realistic and dynamic environment. Since the Continuous treatment captures a climate change-driven effect and a drastic shock can originate from just natural variations, we aim to find whether the nature of the climate change effects alone, can cause different cooperative responses.

The context in which these treatments are tested allows for free communication, includes a delayed publication of the regeneration scheme, has an unknown end to the game, a harvest cap of 15 fish, volatile growth and a regeneration scheme built on environmental uncertainty. These features are explained below.

Communication in our design was costless and unregulated. This has in previous experiments shown to play an important role for cooperative outcomes (Ostrom 2006). Free communication also mimics the field, since communication is seldom restricted or agreements forbidden. The rules for communication only prohibited threats and arrangements for side-payments, since they could undermine the social dilemma and easily render efficient outcomes (and for several ethical reasons).

The purpose of the three-round delay of the publication of the resource regeneration dynamics is to simulate an information-lag prevalent among common pool resource user. It is impossible to monitor resource regeneration dynamics in real-time. Some shocks to an ecosystem, such as coral bleaching, are unknown to fisheries for several years. The construction of the delay was also done to further mimic the field, where cheating is hard to detect. In several cases cheating is never discovered, which we predict will happen in our game (since our pilot studies varied in calculation efforts to discover potential incidents of cheating). Uncertain regeneration has also been adopted by Hine and Gifford (1996) to simulate that future resource growth is seldom known to the fisheries when making their catch decisions.

The game was initially designed as infinite, to test behavior unaffected by the chain-store paradox, since in the field resources will be used by future generations. It is however impossible to play the game forever which may encourage participants to transition to the exit optimal strategy before round 12. There are a few methods to estimate the end, by considering the length of a session (stated as approximately 1.5 hours), the number of rounds in the participant protocols (36 rounds printed), and the maximum variable payment (of SEK 300). None of these information leakages will create incentives to harvest everything before round 12 which is the number of rounds used in our analyses.

The cap of 15 fish is used to simulate that individual common pool resource-agents, seldom can deplete the sea or common pool resource-stock in just one round.

The volatility of the resource regeneration dynamics was included to subdue the differences between the treatments and reduce predictability. The general trend becomes clear after a few rounds, but the volatility makes it difficult to predict the resource regeneration dynamics and determine by mathematical reasoning if agents are cheating or not. In real life, this prediction of the resource regeneration dynamics is seldom done mathematically, but based on generally observed trends, a further motivation for why cheating can only be established after a three-round delay.

The construction of the tables presenting the resource regeneration dynamics was based on an optimal strategy ensuring equal possibility to catch the same number of total fish in all treatments. If participants follow the optimal strategy, they would accumulate a similar number of fish by the end of round 12. The difference between the treatments is therefore not total wealth of the ecosystem, but the structure of the exogenous changes.

The main reason for introducing environmental uncertainty and not environmental risk is to mimic the field. Calculating probabilities for future growth is itself subject to uncertainty, due to the complexity of marine ecosystems. Another factor is that people have difficulties understanding probabilities other than 50–50 which makes the boundary between risk and uncertainty unclear (Schill, Lindahl, and Crépin 2015).

4.2.2 Criticism of design

The choice of allowing communication was made to mimic field conditions, where agents are not prohibited to communicate and shape agreements. However, communication is actually somewhat costly in the field, since all resource users are not always gathered to discuss fishing agreements. This is an observation more difficult to mimic in a lab experiment. Another practical limitation in our experiment is the publication of the stock size. In reality it is impossible to calculate the exact size of a resource at any given time. Furthermore, the growth intervals, the growth, the maximum fishing cap of 15 and the choice of three periods delay are all based on arbitrary values, although based on a logistic reproduction function often similar to field conditions (Clark 1990). Whether or not these variables succeed to capture real-life magnitudes is a general critique of lab experiments and we have therefore followed game designs used in previous common pool resource request games.

Since there was a limited time slot for each group, and since the participants knew this length and the maximum compensation for participating, inferences about the end of the game could be made and complete depletion of the sea becomes a viable option. In real-life, fishermen may take future generations into consideration if they are locked-in and dependent on the fishing industry. Playing a finite number of rounds encapsulates the real-life effect of fishermen who plan to leave the industry. Knowing that there is an end to the game, this should increase the propensity to over-exploit.

Most of the criticism above is applicable to any common pool resource request game and not specific to our study. The advantage of the controlled lab experiments is that the only studied variable differs between the treatments and psychological insights can still be made. If findings are then taken to the field they can be generalized further. A controlled lab experiment therefore serves our purpose of identifying any possible new insight to human behavior, not finding an exhaustive understanding of behavioral responses to global warming.

4.3 Game theoretic analysis of the game

This section incorporates insights from Section 2.1 Game theory and tragedy of the commons, applied to our experiment design. In the context of our game, the *cooperative optimal strategy* would be that participants collectively harvest X units in the first round and then for each subsequent round keep the stock size above 20, for as long as they think the game will continue. The *optimal exit strategy* is in our context a strategy of full depletion that begins when the player believes that the game is approaching its end, or believes that others will defect. However, the exact calculation of the expected reward from following the cooperative agreements is (for the participants) impossible in our game since the growth vary (and this variation is uncertain) during the course of the game. This makes it challenging to make game theoretical predictions without invoking strict assumptions on how participants form beliefs about future growth, and beliefs about how other participants form their beliefs about future growth. Game theory does therefore not provide sufficient guidance to predict outcomes of the game.

However, it can give some guidance in predicting differing outcomes between our treatments. If playing the Continuous (decline) treatment, the growth is lower toward the end of the game, compared to that of other treatments. The payoff from playing a cooperative strategy (staying in the efficient interval) is therefore lower than in other treatments. Therefore, the exit strategy would start at an earlier point. One may therefore, based on this reasoning, hypothesize exit and depletion to happen more often in the Continuous treatment, which would in turn lead to more over-exploitation and lower efficiency, than in the other treatments. However, this hinges on a condition that participants perceive the continuous decline in the game, and believe that the other participants do so as well. The difference between the Uncertainty treatment and the Drastic treatment is only realized after a few periods. From the participants' perspective they play the same game up until this point. Thus from the beginning of the game we hypothesize no significant difference concerning the number of cooperating groups between the Drastic and the Uncertainty treatment. There may be differences after the Drastic shock has been realized but again, without making assumptions on how this change affects participants' forecasting of future growth and forecasting of how other participants will respond to this change, we cannot make any precise predictions.

Since game theory does not take us further, we turn to behavioral considerations and evidence outside the homo economicus models, specifically psychological and behavioral research. This transition in explanatory models is also motivated by the substantial evidence on deviation from the Homo Economicus model, something that also has been documented for behavior in common pool resource dilemmas (Ostrom et al. 2002).

4.4 Behavioral considerations of the game

This section analyzes the game from the nine perspectives described in Section 2.3 A framework based on nine psychological insights. The nine variables have been classified as irrelevant, controlled for, ambiguous or crucial to our hypothesized results.

Group size (6) is held constant to four participants in all treatments and therefore expected to be irrelevant to predict cooperation. Social motives, gender differences and, power and status are out of scope for this study, but variables have been collected to control for these aspects, see Section 6.4 Definitions and modeling. Regarding frames (9), we used a fishing-ground frame to simulate real-life decision making which we expect will positively prime participants to cooperate. Our drastic shock should be perceived as a loss to the participants, which will hurt more than gain. The same phenomena applies to the continuous decline, where losses are constantly perceived by the continuous drop in growth. At the same time, there is no real loss since future gains are just revised to a lower expectation. The effect of this factor in our treatments is therefore ambiguous. The four remaining variables, payoff structure (3), uncertainty (4), communication (7) and causes (8), are all central to our predicted outcomes. Each factor will now be analyzed in the context of our game individually.

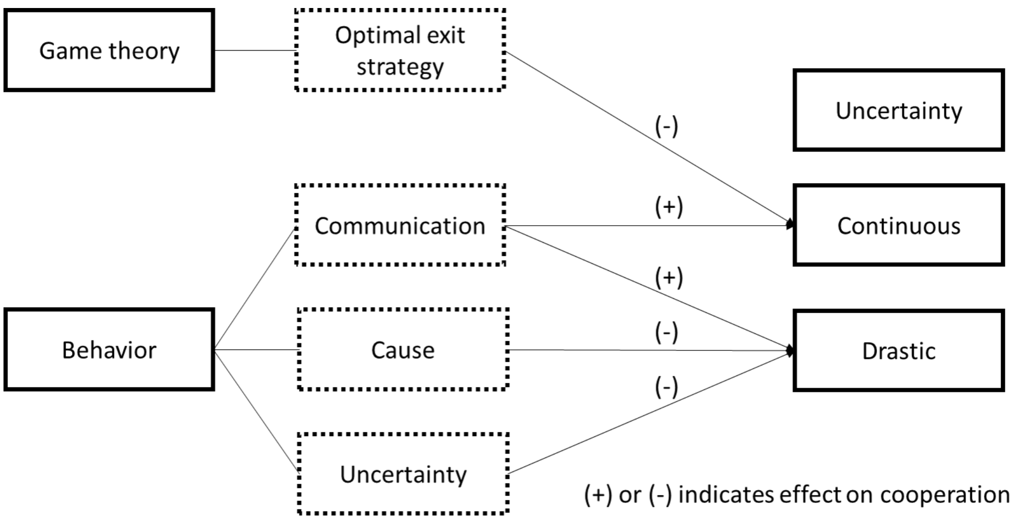
Payoff structure is crucial to our experiment since players meet before, during and after game, which may alter the way participants consider the payoffs of the game. The marginal utility from the monetary value gained by cheating may not exceed the pain of deserting the group. This possible commitment to cooperation is even crucial to the communication variables used in our framework. This, in combination with group identity, has shown to increase cooperation. In the treatments where there are noticeable shocks, such as the Drastic and Continuous treatments, the participants are put to test and may communicate more. This may effectively increase communication and in turn cooperation.

Uncertainty has, as explained by the new generation of experiments, shown to significantly decrease cooperation and often led to complete depletion. One type of uncertainty relates to stock sizes, where proself behavior can be justified by expecting the stock to be larger which legitimizes immoral actions. This type of uncertainty is not present in our design, however the uncertainty of replenishment complicates the establishing of an optimal strategy and the calculation of gains from cheating. The delayed feedback does however facilitate cheating since the risk of getting caught (someone actually doing the calculation) is lower than with immediate feedback. We therefore expect high levels of cheating, but low levels of crossing the optimal interval boundary. The uncertainty variable increases in the Drastic treatment compared to the Uncertainty treatment, since the variability in replenishment is higher. Increased variability, which increases uncertainty, has also in previous studies shown to decrease cooperation (Gustafsson, Biel, and Gärling 1999). We therefore expect the cooperation to be lower in the Drastic treatment.

The causes and changes of the dynamics may also affect cooperation. The importance of path-dependency may differ between the treatments since groups starting out cooperatively might attribute an exogenous shock in the Drastic treatment to natural phenomena, while other groups may believe it to be caused by other participants' greed. We therefore expect the Drastic treatment to be associated with less cooperation, but only for those starting out less cooperative.

Insights from our game theoretic analysis and from the behavioral literature on the commons mainly provide motivations for disparate outcomes between the Continuous and Uncertainty treatment, and between the Drastic and Uncertainty treatment. A continuous decline may lead to more depletion than the uncertainty treatment (based on game theory). Higher uncertainty, and the increased possibility of participants no longer trusting and instead blaming each other, motivates why a Drastic decline will lead to faster depletion of the resource. However, potential effects from differences in communication patterns between the treatments may conflict with above findings, and must therefore be controlled for, see Figure 3 below.

Figure 3: Treatment specific factors



Own illustration of how controlling for communication generates unambiguous hypotheses.

Communication is the only measurable factor of the above variables. Controlling for communication, we have unambiguous hypotheses considering the Uncertainty treatment our control group. In comparison to the control group, we expect there to be negative effects on cooperation and efficiency if communication is accounted for. Our design therefore focuses on unobserved factors affecting cooperation assuming that the magnitude of the climate change in real life will itself cause communication, not necessarily the intrinsic climate change effects.

5 Hypotheses

Our three hypotheses relate back to the three sub-questions of our research question. They all pertain to how the treatments affect cooperation and efficiency. We have used two classifications of cooperation, a stricter one requiring no cheating throughout a game, and a more lenient classification based on the group's Gini. Efficiency is defined in relation to the optimal strategy of each round. Definitions and derivations of variables are explained further in Section 6.4 Definitions and modeling. We also assume that efficiency and cooperation will be positively correlated in all our hypotheses, this is explained further in Section 6.1 Identification strategy.

5.1 Hypothesis 1 – Uncertainty versus Continuous

How does declining resource regeneration affect cooperation and efficiency? This question is tested by comparing cooperation and efficiency in the Uncertainty and Continuous treatments. A continuous decline is expected to advance the transfer to the optimal exit strategy and is therefore expected to reduce cooperation in the last phase of the game. This is expected to lead to higher game-over rates, more over-exploitation and therefore lower efficiency. Scarcity has in previous studies shown to reduce faith in ecosystem survival and our hypothesis is in line with that finding.

1. Declining resource regeneration will decrease cooperation and efficiency.

5.2 Hypothesis 2 – Uncertainty versus Drastic

How does a drastic exogenous shock to the size of a common pool resource affect cooperation and efficiency? This is tested by contrasting the Uncertainty and Drastic treatment. A drastic shock to the resource stock size is associated with higher levels of uncertainty and is hypothesized, for groups with low trust when the shock strikes, to negatively influence trust and cooperation. This negative influence is expected to decrease cooperation and efficiency. However, for groups with high levels of trust, we do not expect to see any changes in cooperation and efficiency.

2. A drastic shock will decrease cooperation and efficiency.

5.3 Hypothesis 3 – Continuous versus Drastic

How does a drastic exogenous shock to the size of a common pool resource contrast to a declining resource regeneration in its effect on cooperation and efficiency? This is tested by comparing the Drastic and Continuous treatment. The theory behind this hypothesis is ambiguous, as both treatments are expected to experience negative effects in contrast to Uncertainty. Whether the game-theoretic prediction of an earlier optimal exit strategy for the Continuous treatment is dominant over the behavioral effects of incorrectly interpreted causes and increased uncertainty, cannot be determined from previous studies. We therefore do not expect there to be any significant differences between our treatments in terms of overall efficiency and cooperation.

3. Changes in cooperation and efficiency caused by a continuous decline will not differ from that of a drastic shock.

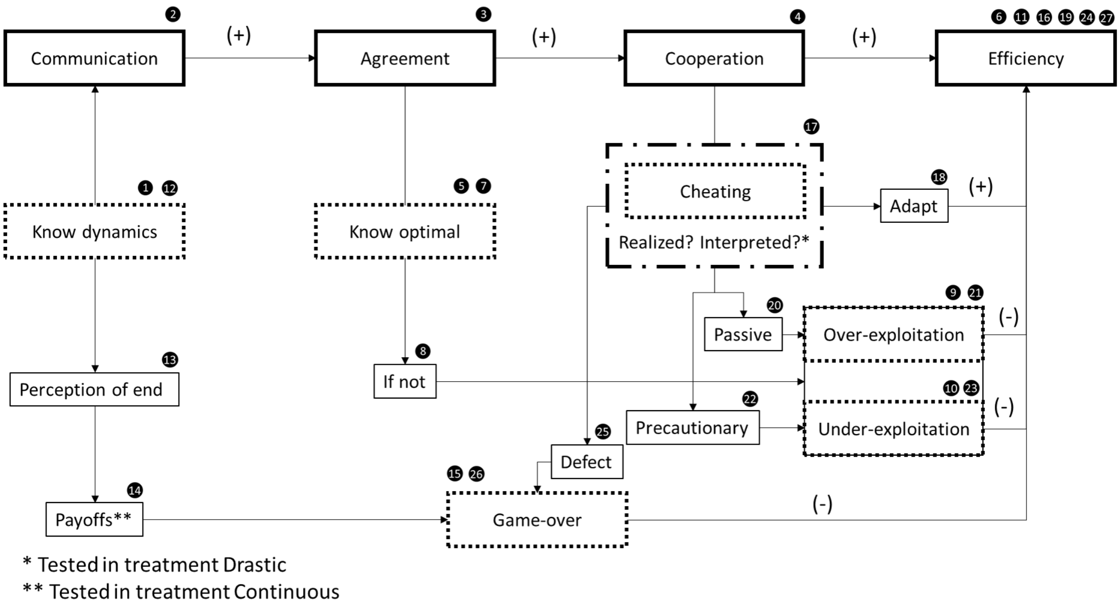
6 Empirical strategy

This section describes how the experiment design tested our hypotheses. We first explain the variables relevant to our identification strategy, then describe our procedure collecting these observations and the complexities involved in the analysis of these observations. Lastly, a section on variable definitions and econometric choices to our methodology.

6.1 Identification strategy

The decision to study efficiency was made to make relevant inferences to real-world scenarios, where sustainable resource extraction is crucial for stable wealth development. This poses the challenge of identification of the factors that drive cooperation aimed at avoiding over-exploitation. A pure efficiency equation would suffer from great endogeneity why many of the underlying factors must be studied separately to clearly understand the effect of the treatments on efficiency. These variables also have a unique value themselves to study, for example if one treatment leads to more over-exploitation. Figure 4 illustrates the interconnections between our variables of interest, the correlation of these will be tested for under 7 Results.

Figure 4: Identification Strategy



Own illustration of measurable variables are affected by treatments and how that affects cooperation and efficiency.

Understanding the dynamics of the game involves the basic insight that the group must cooperate to yield efficient outcomes. To reach a state of cooperation, the group must communicate and the ultimate outcome of the communication is that an agreement is formed (1, 2, 3). If that agreement is followed, assuming that the agreement is based on an understanding of what is optimal, extraction should lead to 100 percent efficiency (4, 5, 6). However, if it is not based on the optimal strategy, under- or over-exploitation may decrease efficiency (7, 8, 9, 10, 11). So may also the insight that the game is going to end, which may result in game-over before round 12 and therefore a lower efficiency (12, 13, 14, 15, 16). The third factor that can cause inefficient outcomes is cheating and how it is dealt with (17). If players solve the cheating, adapt and accept a few deviations, the overall efficiency is unaffected (18, 19). If not reacting at all, the cheating may lead to crossing the boundary of the optimal interval and cause over-exploitation (20, 21, 24). It may also trigger an opposite response, to become precautionary and under-exploit (22, 23, 24). A last reaction is to activate trigger strategies and defect, which may end the game (25, 26, 27). All of these responses are based on whether cheating is realized or not, something that can only be determined with certainty after the three-round delay.

Our experiment aims to control for communication and test the effects of the interpretation of the shock, as to whether it is believed that other participants cheat or not, and if the lower payoffs in the continuous treatment leads to higher defection rates toward the end of the game. These are the only factors we expect to differ between our treatments. The variables, knowledge of the dynamics, perception of the end, knowledge of what is optimal or the quality of agreements are not expected to differ between the treatments, again, controlling for communication. Both payoffs and interpretation are expected to have a negative effect on efficiency, in line with our hypotheses one and two.

6.2 Procedure

The experiments were carried out at The Beijer Insitute of Ecological Economics and at Stockholm School of Economics in March 2018. Experiments were conducted by two different experiment leaders that went through the exact same procedure. All experiments were carried out in English. Upon arrival, the participants first signed a consent form before playing the game that started of with two practice rounds. During the game, the experiment leader took notes of the discussions (in each round) and ranked the group in terms of communication, agreements, cheating, discussion leaders and each participants' knowledge of the resource dynamics, see Table 5 (and Appendix 3). A protocol was used by the players to mark their choices (see Appendix 7). After the experiment, each player filled out a questionnaire (see Appendix 8) with background questions and questions about how they perceived the game. Participants then received their receipts and payments (by cash or swish, a mobile payment system used in Sweden) individually. The payment amounted to SEK 150 (EUR 14.5 and USD 17.9) for participation and an additional SEK 0–300 (EUR 0–29 and USD 0–35.8) based on how many fish each participant harvested during the game. The average variable payout was SEK 137 (EUR 13.0 and USD 15.7).

In total, we performed three treatments with 20 groups each with four participants per group. We also ran two pilot studies of the Continuous and Drastic treatments to test and adjust our methodology. To recruit the total of 408 participants, we included in our selection students from the Royal Institute of Technology (KTH), Stockholm University (SU), Stockholm School of Economics (SSE) and the Karolinska Institute (KI). Posters were put up in both Swedish and English, see Appendix 4 and 5. To ensure that every student at these universities received the invitation to participate, the posters were placed in all unlocked buildings at all four universities. As a complementary action, marketing for the experiment was published on social media, by class announcements in conjunction to lectures and by placing posters in commonly used bathrooms. The participants then signed up through our own-developed website, where they could schedule any available slot, not knowing who the other signed-up participants were, see Appendix 6.

6.3 Criticism of procedure

Now follows a critical discussion of our procedure.

Critically assessing our participant sample, our validity is constrained by only running the experiment with university students studying in Stockholm. Similarly, the employed recruiting/advertising strategy further isolates participants into a subgroup of students who were enrolled in the classes that we visited, study in the buildings where posters were set up, and who were Facebook friends with the different promoters we used.

There are several measures that could have been taken to improve the sample randomness. Some of these measures are mass emails to all students, an even poster distribution across university campuses, etc. In order to control for the biased selection of university students, we asked participants to provide us with their age and educational details such as university, semesters of study, program type, etc.

While student reach is relevant, there are selection biases among the students that signed up. A participant's propensity to sign up for the experiment is individual and unique. Some students need cash, others care for the environment or wish to support research. Here the recruiting message in our posters and pitches comes into the light of criticism. The focal message in advertisements has been the monetary compensation. This might produce a sample bias with generally more income elastic students. To control for this, we asked participants for their monthly income and if the marginal income from participation was significant to the monthly budget.

With regards to methodology during the game, one point of criticism is the oral delivery of instructions to the participants. With two different experiment leaders delivering the instructions slightly differently, the collected data is arguably subject to a significant source of inconsistency. To account for this we included the experiment leader as an explanatory variable in a secondary control regression.

6.4 Definitions and modeling

Due to the complexity described in the identification strategy, a number of data points have been collected. We have also included a number of background variables to control for. There are many ways to define and measure many of the variables collected and constructed and this sections partly aims to explain the definitions and classifications that we have chosen.

One such variable is cooperation. We have split our dataset into three groups based on their cooperation. Perfectly cooperative groups are defined as groups that make agreements and follow their agreements in all rounds. Perfectly round cooperative groups are so in a specific round in which they make and follow an agreement. These are based on the experimenter notes, where for every round, the group's conversation were noted into either making an agreement or not and either all players following the agreement or not. Semi-cooperative groups are groups with a Gini-coefficient below a certain threshold. The Gini-coefficient was calculated for all groups in all rounds and has been used by Schill, Lindahl, and Crépin (2015) as one method to define cooperative groups. The Gini-coefficient is a measure of group inequality quantified as a number between zero and one where a low value indicates low inequality. Schill, Lindahl, and Crépin (2015) defined a cooperative group as one with a Gini below 0.01, however, their game differed from our through immediate feedback which we hypothesize significantly affect cooperation. We also collected data replicating their study and found 62% of the groups to be cooperative. We have decided to classify all groups in the first 62 percentiles in terms of their Gini coefficient to be semi-cooperative. This is also approximately predicted by Hawk-dove theory, where about 10% of the human population acts as hawks, with four hawks in a group the chance of being an all-dove group is $0.9^4 = 65\%$. Semi round cooperative groups are in the first 62 percentile for one specific round. Non-cooperative groups are mutually exclusive to the perfectly cooperative and semi-cooperative.

Efficiency was calculated based on the continuous optimal strategy mentioned in game theoretic considerations. Following the optimal strategy of aiming for the lower bound of the interval with highest growth the catch in each round should equal the difference between the current stock size and the lower bound (20). For stock sizes above 20, the optimal strategy is to harvest the amount with which it exceeds 20. For stock sizes below 20, the optimal strategy is to harvest 0. These values have to be contrasted to the least beneficial strategy of harvesting nothing from a full sea if the stock exceeds 20 and harvesting everything from a sea below 20. That is captured by the following two equations below:

$$1 - \frac{post_n - 20}{30} \tag{2}$$

$$1 - \frac{20 - post_n}{20} \tag{3}$$

Where Equation (2) is valid for stock sizes above 20 and Equation (3) for stock sizes below 20 and $post_n$ represents stock size after catch in round n. These efficiencies are round specific and can be aggregated to group level by averaging the efficiency in every non game-over round.

Over- and under-exploitation happens when there is a discrepancy between the after catch value and 20. If the after catch value is lower than 20, the over-exploitation equals the difference between the after catch value and 20. If the after catch value exceeds 20, the under-exploitation equals the difference between the after catch value and 20. That is quantified in Equation (4) for over-exploitation (valid only for $post_n < 20$) and Equation (5) for under-exploitation (valid only for $post_n > 20$):

$$20 - post_n \tag{4}$$

$$post_n - 20 \tag{5}$$

In the Drastic treatment, following the optimal group strategy will after the negative shock lead a group to fall below the optimal interval, this has been incorporated by adjusting 20 to relevant levels following the optimal strategy (10, 10 and 17).

Hypothesis 2, regarding the Drastic treatment, is split depending on trust. For trusting groups, the cooperation is not expected to be affected, but negatively affected in non-trusting groups. A non-trusting group is one in which there is 1) cheating, and 2) others realizing the cheating before the last round of the crisis (round 6).

Other variables that were taken note of on group level that relates to the identification strategy are communication (scale 1–5 where 5 indicates high level of communication) and group knowledge ("yes" if they understand the dynamics of the game and "no" otherwise).

6.5 Econometric strategy

The purpose of the econometric strategy was to test the hypotheses and understand the underlying drivers of the cooperation and efficiency. It was therefore necessary to estimate the internal correlations between the variables in the identification strategy to explain the eventual differences in efficiency and cooperation for the three treatments. Furthermore, background variables has been used to control for external factors affecting efficiency and cooperation or differing between the treatments. We have also decoded the cooperation and efficiency after three phases of the game, phase 1 (round 1–5), phase 2 (round 6–8) and phase 3 (round 9–12). In round 6–8 the drastic shock happens and influences the optimal strategy. We have done so to isolate the effects of the shocks to the outcome variables. We have also included specifications of under and over-exploitation since these are interesting to study from an ecological perspective, efficiency makes no difference of those while the over-exploitation has different ecological consequences than under-exploitation. We have therefore decided to study that separately to profound our analysis.

Table 5: List of variables

Variable	Source	Interval	Interpretation
Under-exploitation	See equation 5	0–30	30 is highest average under-exploitation in a round
Over-exploitation	See equation 4	0–20	20 is highest average over-exploitation in a round
Efficiency	See equation 2 and 3	0–1	1 is highest efficiency in a round
Gender	Questionnaire	0–1	1 = female, group composition
Age	Questionnaire	-	Age of participant
Nationality	Questionnaire	0–1	1 – all participants are non-Swedish
Education level	Questionnaire	0–5	Question 6 (from no formal to higher)
Perceived communication	Questionnaire	1–5	Question 26
University	Questionnaire	-	Which university the participant is enrolled in
Perceived cooperation	Questionnaire	1–5	Question 23
Perceived leadership	Questionnaire	1–5	Question 27
Perceived trust	Questionnaire	1–5	Question 29
Preceived equal share	Questionnaire	1–5	Question 31
Perceived shock effect	Questionnaire	1–5	Question 15
Perceived cheating	Questionnaire	1–5	Question 32
Individual trust	Questionnaire	1–5	Question 38
Comfortability	Questionnaire	1–5	Question 36
General trust in others	Questionnaire	1–5	Question 36
Shock effect	Questionnaire	1–5	Question 39
Stockholm University	Questionnaire	-	Question 7
KTH	Questionnaire	-	Question 7
Game-Over	Harvest decisions	0–1	1 If game ends before round 12
Gini	Harvest decisions	0–.75	0 is an equal sharing group in round or game
Semi-cooperation	Gini	0–1	1 – Gini in first 62 percentiles in round or game
Non-cooperation	Gini	0–1	1 – Gini in last 38 percentiles in round or game
Agreement	Experimenter notes	0–1	1 – dummy for agreement in a round
Trust	Experimenter notes	0–1	1 for group if any realized cheating in any round
Cheating	Experimenter notes	0–1	1 – any deviation in a round
Realized cheating	Experimenter notes	0–1	1 – if realized cheating in any round of a game
Communication	Experimenter notes	1–5	5 – high degree of communication in a round
Group knowledge	Experimenter notes	0–1	1 – if group understands the game in a round
Group knowing optimal	Experimenter notes	0–1	1 – if group understands the optimal strategy in a round
Understand dynamics from start	Experimenter notes	0–1	1 – individual understands the game before round 2
Perfect cooperation	Agreement and Cheating	0–1	1 – makes agreement and never cheats
Phase 1	-	-	Round 1–5
Phase 2	-	-	Round 6–8
Phase 3	-	-	Round 9–12
Uncertainty	-	-	Dummy for one of our treatments
Drastic	-	-	Dummy for one of our treatments
Continuous	-	-	Dummy for one of our treatments
Non-trust	Experimenter notes	0–1	1 – groups with realized cheating
Over-exploitation share	-	0–1	1 – all groups are over-exploiting
Under-exploitation share	-	0–1	1 – all groups are Under-exploiting

List of all measured variables with specifications and source. Questionnaire can be found in Appendix 8 and experimenter notes in Appendix 3.

We used Jarque-Bera test for non-normality to reject the null hypothesis of normal distribution. Non-parametric Kruskal-Wallis and Mann-Whitney U tests were subsequently used to compare means between treatments. In the regression analysis we used ordinary least square, expect for binary dependent variables that were analyzed with logistic regressions. The data analysis was performed in R version 3.4.3 and tables translated into Latex.

7 Results

With all data collected, we first controlled for any treatment-independent background variables that varied between the three treatments. Table 6 presents the variables that we did not expect to differ between the treatments but showed to do so following a Kruskal-Wallis test on a ten percent significance level.

Table 6: Descriptive statistics for our treatments

	Uncertainty	Continuous	Drastic	p-values
Female	0.412	0.487	0.241	0.005***
	(0.495)	(0.503)	(0.430)	
Age	25.125	23.887	25.288	0.006***
	(4.329)	(3.146)	(4.098)	
Nationality	0.900	0.738	0.800	0.030**
	(0.302)	(0.443)	(0.403)	
Education level	1.844	1.667	1.805	0.050*
	(0.431)	(0.526)	(0.539)	
Understand dynamics from start	0.863	0.988	0.975	0.001***
	(0.347)	(0.112)	(0.157)	

**p<0.1; **p<0.05; ***p<0.01*
Note: The null hypothesis of the Kruskal-Wallis test is that the background variable is evenly distributed between treatments. Please note that only the first four were randomized.

Understanding of dynamics, gender, age, nationality and education level significantly differed between the treatments. The background variables were not expected to differ since groups were assigned to treatments randomly. Neither did we expect the understanding of the dynamics from start to differ between the treatments since the same instructions were read to every group. These significant differences pose the challenge of identifying patterns by means other than that of controlled regression analyses. Understanding of the dynamics is the starting point in our identification strategy and expected to correlate with many of the underlying variables that explain treatment-specific effects on cooperation and efficiency. To still make inferences on differences in means between specific treatments, we have performed a Mann-Whitney U test that indicates which of the treatments significantly differs with respect to all background variables, presented in Table 7.

Table 7: Background Variables

	Uncertainty	Continuous	Drastic	p(U:C)	p(U:D)	p(C:D)
Female	0.412	0.487	0.241	0.343	0.021**	0.001***
	(0.495)	(0.503)	(0.430)			
Age	25.125	23.887	25.288	0.040**	0.354	0.002***
	(4.329)	(3.146)	(4.098)			
Nationality	0.900	0.738	0.800	0.008***	0.078*	0.351
	(0.302)	(0.443)	(0.403)			
Education level	1.844	1.667	1.805	0.020**	0.653	0.081*
	(0.431)	(0.526)	(0.539)			
Understand dynamics from start	0.863	0.988	0.975	0.003***	0.010**	0.566
	(0.347)	(0.112)	(0.157)			
Perceived cooperation	3.763	4.275	4.050	0.024**	0.278	0.204
	(1.380)	(0.981)	(1.124)			
Perceived communication	3.862	4.338	4.075	0.044**	0.648	0.095*
	(1.329)	(0.856)	(1.041)			
Perceived leadership	2.712	3.300	3.100	0.001***	0.033**	0.141
	(1.034)	(0.986)	(0.880)			
Shock effect	3.273	3.696	3.776	0.022**	0.008***	0.599
	(0.550)	(1.090)	(1.091)			
Perceived trust	3.450	4.000	3.525	0.008***	0.900	0.005***
	(1.262)	(0.886)	(1.055)			
Perceived equal share	3.425	3.975	3.362	0.007***	0.670	0.002***
	(1.329)	(1.067)	(1.265)			
Perceived cheating	2.271	1.855	2.211	0.040**	0.681	0.111
	(1.382)	(1.314)	(1.436)			
Comfortability	3.962	4.162	4.162	0.070*	0.046**	0.782
	(0.803)	(0.787)	(0.878)			
	N = 20	N = 20	N = 20			

**p*<0.1; ***p*<0.05; ****p*<0.01

Note: The null hypothesis of the Mann Whitney U test is that the background variable is evenly distributed between each specific treatment. Understanding of dynamics in end, KTH, Stockholm University, Understand dynamics, shock effect, Self-leader, General trust in others also differed between our treatments and are shown in Appendix 1. Please note that only the first four variables were randomized.

The difference in means for understanding of the dynamics from start could be explained by the Uncertainty treatment in which participants reported a lower understanding. Participants in the Uncertainty treatment also reported lower cooperation, less leadership, lower comfort in discussions, less trust in others. These effects may or may not have been driven by the treatment or the initial lower game understanding. In groups playing the Continuous treatment there was more trust, more equal sharing, more communication and less cheating. The significantly higher communication in the Continuous treatment than the Drastic treatment was not expected and highlights the importance to control for this variable in our regressions. The drastic treatment groups perceived the group to respond positively to the shock. The perception of a positive effect on cooperation contrasts to our theoretical predictions that some groups will start blaming each other.

Keeping this in mind, we now turn to test the underlying assumption for all our hypotheses, that cooperation and efficiency is positively correlated. To test this, we investigated the relationship between our identification variables and the three definitions of cooperation. We found the 62nd percentile of Gini-coefficients to be 0.10 and that in total seven out of 60 groups were perfectly cooperative. The relationship between cooperation and efficiency is presented in Table 8.

Table 8: Cooperation and Efficiency

	Perfect cooperation	Semi-cooperation	Non cooperation	p(P:S)	p(P:N)	p(S:N)
Efficiency	0.879	0.813	0.667	0.164	0.005***	0.001***
	(0.103)	(0.110)	(0.156)			
Over-exploitation	0.310	0.785	4.083	0.248	0.005***	0.000***
	(0.783)	(1.432)	(3.636)			
Under-exploitation	3.179	4.410	3.210	0.375	0.915	0.097*
	(2.789)	(3.025)	(2.404)			
Game-over	0.000	0.103	0.524	0.398	0.017**	0.000***
	(0.000)	(0.307)	(0.512)			
Communication	2.343	2.667	2.029	0.172	0.323	0.001***
	(0.435)	(0.596)	(0.636)			
Agreement	1.000	0.928	0.624	0.120	0.001***	0.000***
	(0.000)	(0.149)	(0.284)			
Knowledge	1.000	0.941	0.724	0.171	0.004***	0.000***
	(0.000)	(0.116)	(0.284)			
Cheating	0.000	0.267	0.428	0.001***	0.000***	0.039**
	(0.000)	(0.239)	(0.292)			
	N=7	N=39	N=21			

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$
Note: Mann-Whitney U tests between perfectly perfectly cooperative (P), Semi-cooperative (S) and Non-cooperative (N) groups.

Since the number of perfectly cooperating groups are so few we direct the focus of our analysis to the semi- and non-cooperative groups. We find that non-cooperative groups are on average less efficient, over-exploit more, under-exploit less (on a ten percent significance level), end the game before round 12 more frequently, communicate less, agree less, understand the dynamics worse and cheat more. This is in line with our underlying hypothesis that cooperation is positively correlated with efficiency, although we cannot make certain inferences at this point as several of these variables are expected to be highly collinear. Before investigating collinearity, we studied the relationship between our identification variables and treatment using a Mann-Whitney U test. The result of this test follows in Table 9.

Table 9: Identification variables and treatment

	Uncertainty	Continuous	Drastic	p(U:C)	p(U:D)	p(C:D)
Efficiency	0.761	0.782	0.743	0.839	0.543	0.351
	(0.182)	(0.103)	(0.143)			
Over-exploitation	2.646	1.335	1.837	0.520	0.878	0.617
	(3.774)	(1.947)	(2.622)			
Under-exploitation	3.215	4.551	4.204	0.104	0.298	0.818
	(2.444)	(3.102)	(2.969)			
Perfect cooperation	0.150	0.150	0.050	1.000	0.310	0.310
	(0.366)	(0.366)	(0.224)			
Semi-cooperation	0.600	0.800	0.550	0.178	0.764	0.099*
	(0.503)	(0.410)	(0.510)			
Non-cooperation	0.400	0.200	0.450	0.178	0.764	0.099*
	(0.503)	(0.410)	(0.510)			
Game-over	0.250	0.250	0.250	1.000	1.000	1.000
	(0.444)	(0.444)	(0.444)			
Communication	2.105	2.700	2.525	0.008***	0.095*	0.505
	(0.695)	(0.515)	(0.695)			
Agreement	0.740	0.875	0.850	0.192	0.430	0.572
	(0.328)	(0.200)	(0.193)			
knowledge	0.815	0.915	0.865	0.326	0.775	0.553
	(0.292)	(0.127)	(0.198)			
Cheating	0.325	0.241	0.404	0.345	0.360	0.041**
	(0.281)	(0.248)	(0.262)			
	N = 20	N = 20	N = 20			

**p<0.1; **p<0.05; ***p<0.01*

Note: Mann-Whitney U tests between treatments for identification variables.

We found no significant effect of treatment on efficiency, under-exploitation or over-exploitation. However, the Drastic treatment generated more non-cooperative groups than the Continuous treatment on a 10% level. The significant explanation is cheating, which was higher for the Drastic treatment than the Continuous (on a

5% level). This goes against Hypothesis 3 where no difference was predicted. We also found significantly less communication in the Uncertainty treatment, not surprising due lower volatility or changes and the lower understanding of the dynamics. Since non-parametrical mean comparisons cannot control for communication, we have tested this in an ordinary least squares regression analysis. An important assumption for OLS analysis is that the independent variables are not multicollinear. That was testd in a Spearman correlation matrix. This was also done to test our identification strategy, since it is based on the identification variables. The Spearman correlation matrix follows in Table 10.

Table 10: Spearman correlation matrix

	Efficiency	Under exploitation	Over exploitation	Perfect cooperation	Semi-cooperation	Non-cooperation	Game-over	Communication	Knowledge	Cheating	Agreement
Efficiency											
Under-exploitation	-0.340***										
Over-exploitation	-0.565***	-0.433***									
Perfect cooperation	0.298**	-0.096	-0.272**								
Semi-cooperation	0.435***	0.217*	-0.498***	0.267**							
Non-cooperation	-0.435***	-0.217*	0.498***	-0.267**	-1.000***						
Game-over	-0.483***	-0.148	0.618***	-0.210	-0.464***	0.464***					
Communication	0.220*	0.286**	-0.332***	-0.086	0.421***	-0.421***	-0.389***				
Knowledge	0.414***	0.222*	-0.579***	0.285**	0.493***	-0.493***	-0.788***	0.577***			
Cheating	-0.122	0.092	0.054	-0.518***	-0.290**	0.290**	0.019	0.195	0.057		
Agreement	0.391***	0.350***	-0.643***	0.328**	0.620***	-0.620***	-0.659***	0.659***	0.817***	0.064	

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Note: The correlation between identification variables does not imply causation. The Spearman correlation was used instead of Pearson correlation for being non-parametric.

The majority of the variables from our identification strategy were highly correlated. We will therefore avoid including a correlated pair of variables in our regressions, to avoid difficulties in our statistical inferences.

We also found that efficiency had significant correlations with all variables except for cheating (on ten percent significance or lower), in line with our identification strategy (since the effect of cheating is determined by its interpretation). The signs, or direction of the correlations for efficiency, were all in line with our identification strategy. The same goes for cooperation, which indicates that our identification strategy accurately portrays the relationship between our studied variables. However, the effects of our treatments are not captured in a correlation matrix, we therefore performed a regression analysis.

Table 11: Logistic Regression

	Dependent variable:							
	Non-cooperation	Semi-cooperation	Perfect cooperation	Knowledge	Agreement	Game-over	Cheating	Non-cooperation phase 3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Continuous	0.502	−0.502	−1.236	−0.291	−0.190	1.639*	−0.719	1.271
	(0.885)	(0.885)	(1.274)	(1.205)	(1.024)	(0.961)	(0.756)	(0.783)
Drastic	1.423*	−1.423*	−1.847	−0.309	0.128	0.853	0.118	1.651**
	(0.848)	(0.848)	(1.522)	(1.015)	(0.925)	(0.883)	(0.687)	(0.797)
Communication	−1.840***	1.840***	−0.229	2.219***	2.249***	−2.213***	0.470	−1.470***
	(0.651)	(0.651)	(0.732)	(0.826)	(0.781)	(0.718)	(0.458)	(0.519)
Understand dynamics from start	−4.145	4.145						
	(3.024)	(3.024)						
Age			−0.637					
			(0.417)					
Nationality	2.481	−2.481	−2.905*			2.270		1.305
	(1.538)	(1.538)	(1.642)			(1.578)		(1.150)
Constant	4.990	−4.990	16.971	−2.735*	−3.438**	1.206	−1.701	1.479
	(3.134)	(3.134)	(10.838)	(1.580)	(1.593)	(1.712)	(1.109)	(1.428)
Observations	60	60	60	60	60	60	60	60
Akaike Inf. Crit.	68.747	68.747	47.154	28.247	41.389	62.094	72.798	75.653

**p<0.1; **p<0.05; ***p<0.01 Note: Control variables evaluated on significance based on the background variables significantly differing between treatments.*

Table 12: OLS Regression

	Dependent variable:					
	Efficiency	Over-exploitation	Under-exploitation	Communication	Gini	Efficiency phase 3
	(1)	(2)	(3)	(4)	(5)	(6)
Continuous	−0.025	−0.308	0.858	0.356*	−0.018	−0.201*
	(0.047)	(0.907)	(0.956)	(0.207)	(0.036)	(0.105)
Drastic	−0.050	−0.087	0.645	0.326	0.022	−0.106
	(0.045)	(0.879)	(0.927)	(0.197)	(0.034)	(0.114)
Communication	0.079***	−1.734***	0.827		−0.015	0.139*
	(0.029)	(0.554)	(0.585)		(0.023)	(0.075)
Understand dynamics from start				0.927**	−0.095	
				(0.386)	(0.069)	
Age				−0.087*	0.015*	
				(0.047)	(0.008)	
Constant	0.594***	6.302***	1.472	3.491***	−0.131	0.465**
	(0.068)	(1.314)	(1.385)	(1.210)	(0.220)	(0.182)
Observations	60	60	60	60	60	52
R^2	0.130	0.179	0.073	0.251	0.183	0.104
Adjusted R^2	0.084	0.135	0.023	0.196	0.107	0.048
Residual Std. Error	0.139 (df = 56)	2.682 (df = 56)	2.828 (df = 56)	0.606 (df = 55)	0.103 (df = 54)	0.300 (df = 48)
F Statistic	2.796** (df = 3; 56)	4.073** (df = 3; 56)	1.469 (df = 3; 56)	4.606*** (df = 4; 55)	2.414** (df = 5; 54)	1.856 (df = 3; 48)

**p<0.1; **p<0.05; ***p<0.01 Note: Control variables evaluated on significance based on the background variables significantly differing between treatments.*

From Table 11 we found the Drastic treatment to negatively effect cooperation, specifically in the last phase of the game. We also found the Continuous treatment to increase defection rates, shown by a higher number of game-overs, which was in line with our hypotheses. We also expected the Continuous treatment to lower cooperation, which the coefficient indicated, however at an insignificant level. Table 12 shows a negative efficiency coefficient from our treatments, however at an insignificant level. We are therefore inconclusive to whether such an effect exists. The Continuous treatment led to a lower efficiency in the last phase, but only on a ten percent significance level. We found the Continuous treatment to increase communication, somewhat in line with our predictions.

Relating back to our hypotheses, we found the Drastic treatment to decrease overall cooperation, both in comparison to the Uncertainty treatment (in line with our Hypothesis 2 – but only on a ten percent significance level) and the Continuous treatment (in contrast to our Hypothesis 3). All other results are in the predicted direction, however not significant. We therefore remain inconclusive as to whether the exogenous changes have affected cooperation or efficiency.

7.1 Explorative expansion and data analysis

To further understand the causality of the shocks and changes to the regeneration we divided the game into three phases. We then studied the development of central variables during the course of the game. Table 13 describes the development of efficiency and cooperation for the treatments and a Mann-Whitney U test for potential mean differences between them.

Table 13: Splitting the game into three phases

	Uncertainty	Continuous	Drastic	p(U:C)	p(U:D)	p(C:D)
Efficiency1	0.789	0.798	0.784	0.957	0.499	0.695
	(0.123)	(0.115)	(0.111)			
Perfect cooperation1	0.400	0.600	0.460	0.073*	0.545	0.197
	(0.355)	(0.337)	(0.325)			
Semi-cooperation1	0.440	0.720	0.680	0.015**	0.046**	0.645
	(0.370)	(0.293)	(0.314)			
Non-cooperation1	0.560	0.280	0.320	0.015**	0.046**	0.645
	(0.370)	(0.293)	(0.314)			
Efficiency2	0.732	0.816	0.646	0.613	0.292	0.130
	(0.269)	(0.155)	(0.336)			
Perfect cooperation2	0.417	0.567	0.450	0.220	0.725	0.348
	(0.431)	(0.406)	(0.347)			
Semi-cooperation 2	0.567	0.667	0.467	0.497	0.393	0.080*
	(0.447)	(0.390)	(0.349)			
Non-cooperation2	0.433	0.333	0.533	0.497	0.393	0.080*
	(0.447)	(0.390)	(0.349)			
Efficiency3	0.773	0.636	0.742	0.041**	0.220	0.494
	(0.317)	(0.340)	(0.242)			
Perfect cooperation3	0.338	0.487	0.287	0.231	0.794	0.115
	(0.400)	(0.401)	(0.365)			
Semi-cooperation3	0.600	0.550	0.412	0.797	0.125	0.252
	(0.447)	(0.426)	(0.391)			
Non-cooperation3	0.400	0.450	0.588	0.797	0.125	0.252
	(0.447)	(0.426)	(0.391)			

**p<0.1; **p<0.05; ***p<0.01 Note: Mann-Whitney U tests between treatments for game phases. Phase 1: round 1-5, Phase 2: round 6-8, Phase 3: round 9-12.*

We found the cooperation in phase one to be significantly lower in the Uncertainty treatment. As our first background analysis showed, less knowledge from start could be the explanation since there is no other theoretical explanation for less cooperation in the Uncertainty treatment than in the Drastic treatment (other than slightly lower growth). The game then stabilized between the treatments in Phase 2, where the only difference was less cooperation in the Drastic treatment than in the Continuous (on a ten percent significance level), again in conflict with our hypotheses. This also conflicts with participant perception of the shock positively affecting cooperation (adding to our skepticism of hastily including subjective questionnaire-based control variables). The last phase did however confirm the hypothesis that Continuous declines generate lower efficiency towards the end, (a relationship true on the ten percent significant level controlling for communication, shown in Table 12).

Following our identification strategy, we also split the underlying variables to cooperation and efficiency into three game phases, see Table 14 and Table 15.

Table 14: Breaking Down Cooperation

	Uncertainty	Continuous	Drastic	p(U:C)	p(U:D)	p(C:D)
Game-over1	0.050	0.000	0.000	0.342	0.342	NaN
	(0.224)	(0.000)	(0.000)			
Gini1	0.126	0.061	0.087	0.095*	0.482	0.151
	(0.129)	(0.068)	(0.083)			
Agreement1	0.760	0.920	0.950	0.135	0.098*	0.983
	(0.376)	(0.238)	(0.128)			
Communication1	2.670	3.270	3.230	0.042**	0.043**	0.989
	(0.859)	(0.706)	(0.718)			
Knowledge1	0.870	0.980	0.980	0.151	0.151	1.000
	(0.299)	(0.089)	(0.089)			
Cheating1	0.350	0.260	0.460	0.506	0.270	0.058*
	(0.343)	(0.252)	(0.325)			
Game-over2	0.050	0.000	0.250	0.162	0.225	0.019**
	(0.308)	(0.000)	(0.444)			
Gini2	0.172	0.110	0.298	0.450	0.142	0.003***
	(0.195)	(0.139)	(0.219)			
Agreement2	0.817	0.933	0.867	0.360	0.926	0.244
	(0.382)	(0.232)	(0.274)			
Communication2	2.133	2.517	2.567	0.151	0.110	0.613
	(0.783)	(0.688)	(1.098)			
Knowledge2	0.900	0.983	0.883	0.534	0.472	0.151
	(0.308)	(0.075)	(0.271)			
Cheating2	0.383	0.267	0.333	0.245	0.832	0.300
	(0.394)	(0.399)	(0.306)			
Game-over3	0.100	0.300	0.050	0.123	0.573	0.042**
	(0.308)	(0.470)	(0.224)			
Gini3	0.115	0.133	0.164	0.754	0.259	0.209
	(0.140)	(0.179)	(0.146)			
Agreement3	0.613	0.787	0.700	0.289	0.681	0.628
	(0.469)	(0.337)	(0.434)			
Communication3	1.387	2.087	1.613	0.052*	0.494	0.270
	(1.034)	(1.092)	(1.140)			
Knowledge3	0.650	0.800	0.713	0.346	0.729	0.613
	(0.469)	(0.340)	(0.439)			
Cheating3	0.275	0.200	0.388	0.475	0.419	0.142
	(0.323)	(0.276)	(0.393)			

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$ Note: Mann-Whitney U tests between treatments for game phases. Phase 1: round 1-5, Phase 2: round 6-8, Phase 3: round 9-12.

The Continuous treatment started out in the first phase with more communication and a lower Gini coefficient than Uncertainty. Phase 2 then followed with lower game-over rates that in Phase 3 turned from 0 to 30 percent of all groups. The Drastic treatment started out with more cheating in Phase 1, experienced more game-overs and a higher Gini-coefficient than the Continuous treatment in Phase 2 but stabilized into no significant differences in Phase 3.

A similar split of the data to isolate the shocks was made for the variables affecting efficiency, see Table 15.

Table 15: Breaking Down Efficiency

	Uncertainty	Continuous	Drastic	p_uc	p_ud	p_cd
Over-exploitation1	1.097	0.060	0.470	0.081*	0.155	0.896
	(2.224)	(0.185)	(1.628)			
Under-exploitation1	4.683	5.980	5.780	0.239	0.330	0.860
	(2.830)	(3.568)	(3.626)			
Over-exploitation share1	0.183	0.040	0.080	0.098*	0.154	0.948
	(0.288)	(0.105)	(0.238)			
Under-exploitation share1	0.747	0.860	0.820	0.222	0.234	0.811
	(0.294)	(0.206)	(0.324)			
Stock after catch1	23.260	25.920	25.310	0.074*	0.120	0.776
	(4.867)	(3.647)	(4.593)			
Over-exploitation2	3.667	0.867	3.117	0.264	0.987	0.099*
	(6.099)	(2.161)	(4.119)			
Under-exploitation2	2.544	4.217	2.750	0.141	0.643	0.140
	(3.313)	(4.467)	(3.489)			
Over-exploitation share2	0.298	0.133	0.450	0.301	0.436	0.065*
	(0.443)	(0.274)	(0.510)			
Under-exploitation share2	0.579	0.650	0.500	0.585	0.773	0.389
	(0.413)	(0.382)	(0.513)			
Stock after catch2	17.933	23.350	11.433	0.091*	0.008***	0.000***
	(9.056)	(5.520)	(7.613)			
Over-exploitation3	3.598	5.500	3.400	0.833	1.000	0.628
	(6.675)	(7.820)	(5.547)			
Under-exploitation3	1.412	2.675	2.650	0.255	0.619	0.851
	(2.372)	(3.414)	(3.070)			
Over-exploitation share3	0.324	0.346	0.300	0.987	0.823	0.800
	(0.393)	(0.429)	(0.403)			
Under-exploitation share3	0.471	0.575	0.500	0.501	1.000	0.675
	(0.374)	(0.422)	(0.453)			
Stock after catch3	15.100	16.637	14.438	0.175	0.828	0.329
	(9.724)	(10.707)	(10.750)			

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$ Note: Mann-Whitney U tests between treatments for game phases. Phase 1: round 1-5, Phase 2: round 6-8, Phase 3: round 9-12.

Again, we see that the game stabilizes and evens out toward the end of the game. This indicates that most treatment effects are temporary for different phases of the game but that they were adapted to fairly well. We did find less over-exploitation in the Continuous treatment from the start in comparison to Uncertainty, and slightly less over-exploitation in Phase 2 than the Drastic treatment. Differences in stock sizes are treatment driven (specifically the Drastic stock size in Phase 2) and cannot be isolated to any behavioral response in our identification strategy. We also tested whether trust was related to the Drastic shock. In our hypothesis, we expected groups with lost trust would react negatively to the shock. We defined non-trusting groups as groups in which there was cheating that was realized by the group. In total, six Drastic groups and five Uncertainty groups were defined as non-cooperative. We therefore performed a regression with efficiency as the dependent variable, controlling for communication, to find if the interaction between the Drastic treatment and non-trusting decreases efficiency.

Table 16: The importance of trust for managing shocks

Efficiency	(Intercept)	Drastic	Communicate	Non-trust	Drastic*Non-trust
Estimate	0.638***	-0.150***	0.109***	−0.260***	0.211**
Std. Error	0.070	0.052	0.030	0.057	0.081
	N=30	R^2=.582	$\bar{R}^2$=.515	RSE=0.102	F=8.710***

**p<0.1; **p<0.05; ***p<0.01*

Note: RSE = Residual Standard Error (with df = 25), F-statistic calculated with df = 4; 25.

We found the opposite to be true, with a positive coefficient of the interaction variable and a negative effect of non-trusting on efficiency, we conclude that the combination of both does not decrease efficiency. The Drastic treatment did not have the in the identification strategy described effect on the interpretation of cheating in combination with the shock. The groups may have realized the cheating, then solved their trust-issues, and managed through the crisis and therefore avoided a lower efficiency. We therefore reject the expected mechanism that non-trusting would make participants attribute exogenous changes to cheating.

8 Discussion

The purpose of this study was to test behavioral responses to exogenously driven changes to the resource dynamics of a common pool resource. By means of a simulated game in a laboratory setting, we controlled for communication between our three treatment groups. We found that a continuous decline in the resource growth decreased extraction efficiency with a falling growth-stock ratio, and that a drastic shock to the resource size decreased overall cooperation. Both of these findings were confirmed on a ten percent significance level. We did not find any significant impact on cooperation from the Continuous decline treatment nor any significant impact on efficiency from our Drastic shock treatment. This was surprising since the correlation between cooperation and efficiency (considering all treatments) was positive on a one percent significance level. We therefore split the twelve-rounds game into three phases to analyze the development of our collected sub-variables vis-à-vis cooperation and efficiency.

Doing so, we found that the continuous decline in growth increased the number of game-overs in the last phase of the game. This is in line with our game theoretical predictions, that toward the end, the growth in the Continuous setting was low enough for the resource users to harvest the remains. This happened in 30 percent of the groups, while 70 percent sustained the resource. Using a binary division of cooperative groups implied that groups still sustaining the resource could be classified as (semi-) cooperative. A few agreements were made in these groups to collectively harvest the remaining resources, which also explains why cooperation was not negatively affected. All of this supports the hypothesis that the Continuous decline can have negative effects on long-term extraction efficiency, when the resource growth is considered too low in comparison to the stock size. Relating to climate change-driven effects, this could also be true in real life. When growth is low, the faith in an ecosystem's survival decreases, which speeds up its depletion. This is an alarming finding suggesting faster extinction then previously predicted. Although such conclusions are outside our scope of research, we propose to study this potential effect closer in the future.

Splitting the game into three phases, we also found that the drastic shock to the resource stock size caused a temporary increase in group inequality, over-exploitation and non-cooperation. However, the effect was only temporary and in the last phase of the game, only cooperation remained significantly lower. We also tested if the Drastic treatment would trigger a blame-game, where participants would incorrectly attribute the exogenous shock to cheating, but did not find this to be true. Yet, cooperation remain significantly lower in our Drastic treatment, especially toward the end of the game. One explanation is that the Drastic treatment was associated with a higher volatility in the regeneration. Marginal cheating would therefore more likely be interpreted as environmental fluctuations rather than realized cheating. Marginal cheating decreases cooperation, but not necessarily efficiency. In fact, it can even increase efficiency in under-exploiting groups. This is in line with our other findings, that efficiency was not (significantly) negatively affected by the Drastic treatment.

Our findings are in line with many of the previous studies cited in our literary review. Despite being outside the limitation of scope, our study confirms the importance of communication to cooperation and efficient extraction, significant on a one percent level. We also found surprisingly high levels of cooperation, despite our game design incorporating both strategic and environmental uncertainty, which has caused ecosystem collapse in several previous studies (Walker and Gardner 1990). This highlights the importance of locally shaped agreements imposed from within. Our continuous decline treatment also increased communication, suggesting that local adaptation to (potential) external crises through seeking agreements can counteract the uncertainty of future growth, in line with findings from Schill, Lindahl, and Crépin (2015). Many of our groups, regardless of treatments, under-exploited more than predicted by game theory, leaving space for cheating. This suggests that participants trusted each other more than the environment and that uncertainty caused precaution. Sharing knowledge about future uncertainties may therefore avoid resource depletion.

This study contributes with a first test of an experimental design that incorporates both strategic and environmental uncertainty, and shows that it does not necessarily lead to a collapse of the ecosystem. With minor adjustments, the design can be taken to the field and still incorporate many complexities prevalent in the real world. We argue that studying exogenous changes in the context of uncertainty and communication is an important contribution to existing research. Ostrom (2006) argue that incorporating ecological contexts into social dilemma studies is an emerging field, developing important insights as to whether cooperation will emerge. Varying these ecological features to incorporate different types of uncertainty is one suggestion for future research to better understand which types of environmental uncertainty comply with cooperation, when communication is allowed. Stock size uncertainty, growth uncertainty, growth interval uncertainty and delayed feedback (as in our treatment), have all yielded slightly different results in previous studies. Another variation is cost of communication. Communication is seldom forbidden in real life, but neither is it costless. Merely the possibility to communicate does not ensure communication, especially if there is a cost (or opportunity cost) associated with it. We also suggest further research to measure the effect of path dependency. We observed signs of high cooperation in the Continuous treatment due to beneficial conditions from the start. The calm state for the first five rounds in the Drastic treatment may also have caused more cooperation than if the shock happened earlier. We conclude that there is a multitude of ecological variations that can be translated into an experimental setting, if the final aim is to predict resource development. We also highlight the importance of policy-relevance to these studies, as the climate threat is urgent. Our results suggest that for the preservation of species with expected declines growth, policy-makers should reduce resource users' dependence on the resource. Failure to do so significantly (at a ten percent significance level) increases the risk of resource depletion. We do not recommend this lab experiment as a basis for policy, but if shown more universal, for example in the field, the finding can guide future policy. Our findings highlight one of Ostrom's institutional principles for effective resource management, that the resource users' should select their own monitors. In our design, calculating instances of cheating was possible but did not always emerge spontaneously, which caused unequal outcomes for the participants.

A critical problem to our findings is that the understanding of the resource dynamics differed between our treatments. Although the questionnaire response could be treatment-driven, we did not expect there to be any difference between our treatments as we used the same instructions for all groups. These findings also hold when controlling for participants' rating of how well the experiment leader conveyed the dynamics of the game through the instructions, see question 20 in Appendix 8. Being a crucial factor in our identification strategy, the discrepancy in understanding was problematic, as we expected very different responses from groups unaware of the resource dynamics. This is also an explanation for the intense under-exploitation, indicating that participants trusted each other more than the dynamics of the game. Although a perfect understanding of ecosystem functions is not present in the real-world either, we did not expect there to be treatment varying effects. This complicated our identification strategy and is the reason why we chose to control for this in some of our regressions. For future research we therefore propose a simpler game with fewer variations that can yield better game understanding.

In our identification strategy we found strong correlations between many of our variables. One exception to this is that cheating was not correlated with efficiency, under-exploitation, over-exploitation, game-over, communication or knowledge (only with cooperation, which is endogenous to its definition). This suggests that the response to cheating is more important than its occurrence. Rule-violators will always be present, even more in an uncertain environment where a poor understanding of the dynamics can be exploited. It is the detection of cheating, not cheating itself, that causes trigger responses that potentially affect extraction efficiency. In our setting, detection of cheating required calculations, note-taking and signals to the other players that they are not trustworthy. Although the Drastic treatment caused temporary negative effects on cheating, it did not decrease efficiency.

8.1 Conclusion

We have tested two types of exogenous changes, to the regeneration and size of a common pool resource, on cooperation and efficiency. One Continuous decline in the growth, simulating climate change-driven deterioration of ecosystem services and one Drastic shock to the resource size simulating, climate change-driven or not, extreme weather phenomena. In our laboratory design setting, with uncertain regeneration, free communication and delayed feedback of growth, we measured behavioral responses to these ecologically simulated changes. We found that a drastic weather simulated shock could decrease cooperation in contrast to both stable resource dynamics development and a continuous decline, on a ten percent significance level. We also found deterioration in growth to increase the probability of complete depletion (and lowering the efficiency) toward the end of the resource lifetime, suggesting fast extinction when growth-stock ratio is low. Our findings of the effect of the Drastic shock on efficiency and the overall effects of the Continuous decline were insignificant, why we remain inconclusive of potential behavioral responses.

To our knowledge few studies investigate this realistic relationship between uncertainty and communication. From our results, we uncovered insightful indications of the multifaceted complexity that uncertainty entails. The uncertainty from delayed feedback caused extensive under-exploitation, suggesting that participants trust each other more than the resource dynamics. This left room for marginal cheating, negatively effecting cooperation, however not putting the stock size or growth at risk. In fact in these cases of heavy under-exploitation, cheating increased efficiency. This suggests that it is the realization of cheating, rather than the cheating itself, that causes efficiency to deteriorate. Insights such as these demonstrate how different game designs can accurately incorporate real-world conditions. This is one of the main contribution of our study, which we hope will be one additional step along the path to understanding what drives behavior in the face of climate change.

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Appendices

Appendix 1 – Other treatment differing background variables

Table 17: Appendiced background variables

	Uncertainty	Continuous	Drastic	p(U:C)	p(U:D)	p(C:D)
Understand dynamics in end	0.875 (0.333)	0.975 (0.157)	0.975 (0.157)	0.017**	0.017**	1.000
KTH	0.637 (0.484)	0.450 (0.501)	0.600 (0.493)	0.018**	0.628	0.059*
Stockholm University	0.138 (0.347)	0.263 (0.443)	0.112 (0.318)	0.049**	0.636	0.016**
Understand dynamics	3.688 (0.908)	4.000 (0.857)	3.600 (0.894)	0.024**	0.619	0.005***
Self-leader	2.337 (0.954)	2.700 (0.906)	2.750 (0.849)	0.029**	0.013**	0.785
General trust in others	3.538 (1.169)	3.663 (1.201)	3.850 (1.126)	0.424	0.065*	0.317

Appendix 2 – Instructions

Normal text: read out loud the participants *Italics: Things you should do*

Welcome and thank you for coming to participate in this activity today! During this activity, you will first play a game and then fill out a survey. The entire activity will take approximately 1.5 hours of your time. In this game you will be allowed to make some decisions. You will receive 150 kronor for your participation in this activity. Depending on the decisions you make in the game, you can earn extra money. You will receive the money after completion of game and survey (paid in private). We use money because the exercise requires that you make some economic decisions that have consequences. It is to make the game realistic. Before we start we want you to sign a consent form. The consent form says you are here voluntarily. It also informs you that the decisions that you take today will be anonymous. It will not be known to the other participants. Also when we analyze the results we will use numbers to identify you.

Explain common access to a fishing water (e.g. the sea)

In this game, we want you to imagine that you in this group have common access to a fishing ground (e.g. the sea). Although in reality it is impossible to know exactly how much fish there is in the sea, in this game we ask you to pretend that we can know how much fish there is. Each of you can catch this fish from this common resource.

Explaining the game, catch, procedure etc

The game we will play lasts several rounds and in each year you make an individual and anonymous decision of how much fish to catch in that particular round. For each fish you catch you get SEK 5. So for example if you catch 20 fish you will earn 20*5 = SEK 100. So how do we keep track of you catch?

Introduce the records. Explain the procedure. Show the decision protocol (which should be foldable to ensure anonymity)

In each round/period you mark how much fish you want to catch. You can choose a number between 0 and 15. These protocols will be collected by me after each decision round. We will in each round sum up the fish catch of the whole group. We will calculate the new stock size. You will get this information from us before the round starts. *Explain that the resource is dynamic and grows*

Now we will explain how the fish grows, which will be indicated on the whiteboard. The fish reproduce/grows between each new round. How much the fish stock grows depends on how many fish your group left in the previous round. We start with 50 fish in the first round. Exactly how the fish stock grows is unknown to you in advance. However, we will in each round tell you how it grew 3 years ago. The resource growth may, or may not, change between the rounds, you will only know how it looked 3 years after you have made your decisions. If you play year 2018, you will know how the fish grew in 2015. In the next round, in 2019, you will know how the fish grew in 2016. In the round after that, in 2020, you will know how the fish grew in 2017. This is to simulate that scientific reports are produced with a delay and that it is impossible to know how the resource grows in the future. The levels may therefore fall, increase or remain the same during the game, but the relationship between the levels will remain roughly the same. We will now present the resource dynamics, and use the example of how it grew exactly 3 years ago. If again, we play in year 2018, I will now present how the stock grew from 2015–2016. We start with 50 fish in the stock. If after the catch in 2015, there was 46–50 fish left in the stock, it did not grow until 2016. This because there is no room for reproduction. If there were 35–45 fish in the stock after catch in 2015, there would be 5 more fish in 2016. If there is so much fish in the sea as in this "hypothetical" case – they may compete for food and have a hard time of finding each other to reproduce with the result that the fish stock does not grow so much. If there was 20–35 fish in the stock after catch in 2015 (middle pool/pond/stock), there would be 10 more fish in 2016. Here there is enough fish so that they can find mating partners and not too much so they compete for food. If there was 5–19 fish in the stock after catch in 2015 (small pool/pond/stock), there would have been 5 more fish in 2016. If there is too little fish they don't find enough partners and cannot reproduce. For stock sizes below 5, the fish stock did not grow at all.

The growth can be positive or negative, but if it is positive, it will always be higher for levels between 20–34 and if it is negative, it will never be "more negative" in stock sizes outside of the 20–35 interval. The growth will vary over the course of the game, but that is the only thing with this game that will vary, everything else will stay the same. The growth was determined in beforehand, so was the number of rounds, you will only directly affect the stock size through your decisions. As long as there is fish to catch, the game continues for a number of rounds and you can earn money. We will not tell you the exact number of rounds. If there is no fish the game ends and you will not earn any more money. *If someone asks about how to share a harvest that is larger than the stock, answer: we will share proportionally according to your catch claim.*

Examples Let's say the resource dynamics did not change from how it grew 2015–2016 and from 2018–2019, then the resource would grow as following: There are 50 fish in the beginning of the experiment. If you, for example, catch together 20 fish (for example 4+6+7+3) there are 30 fish left and the stock will then grow with 10 more fish. Then the fish stock will consist of (50-20+10) = 40 fish in round 2. So now there is 40 fish. Let's, for simplicity, assume the same growth in period 2019–2020. If you then catch 24 fish in total (6+6+6+6) there are 16 fish left and the stock will then grow with 5 more fish. Then the fish stock will consist of (40-24+5)

= 21 fish in 2020. But note that you never know in advance exactly how the fish will grow, this may change over the years and you will only know three years after you make your decision. So if you catch 20 fish, there are 30 left, but the will not necessarily grow by 10, it could grow by 15, or 5, or decline by 5, or anything else. You will only know exactly three years later.

Communication? What can you talk about? You should not show the catch decision on balance sheet or the protocol to the other people in your group (point to the balance sheet and protocol again). This is strictly forbidden and the experiment will be interrupted immediately if this happens. However, you can talk to each other. You can talk about the game, the rules and your decisions but you cannot make any threats or arrangements for side-payments during or after this activity.

In case you have any questions just ask me.

Summary:

- The four of you share this fishing ground
- In each round you will make an individual and anonymous decision of how many fish to catch
- Each person can choose between 0 and 15 fish in every round
- As long as there is fish left the game continues (until the experimenter leader stops)
- The fish recovery depends on how much fish there is after the catch
- We only tell you how the stock grew 3 years ago
- How the fish stock grows may change during the game, and can be positive or negative never lower outside the 20–34 interval
- Communication is allowed during the whole game
- Each fish is worth SEK 5
- We do not tell you how many rounds we will play

We will now play a few practice rounds. The practice round does not matter for your earnings and the game will be reset to the stock size of 50 again when the real game begins. Questions?

*After having played a test round.*We can now start the game which means that from now you earn money based on your decisions.

Appendix 3 – Experimenter notes

Table 18: Experimenter notes in a list

Question	**Answer method**
Harvest decision	Individual between each round
Communication	Scale 1–5 between each round
Agreements	Yes or no on group level between each round
Knowledge of resource dynamics	Yes or no on group level between each round
Breaking the agreement	Yes or no on group level between each round
Understanding of dynamics in beginning of game	Yes or no on individual level, once per game
Understanding of what is optimal in beginning of game	Yes or no on individual level, once per game
Understanding of dynamics during the course of the game	Yes or no on individual level, once per game
Understanding of what is optimal during the course of the game	Yes or no on individual level, once per game
Discussion leader	Yes or no on individual level, once per game
Quite during discussions	Yes or no on individual level, once per game
Breaking agreements	Yes or no on individual level, once per game
Is there someone who says nothing?	Yes or no on group level, once per game
Does the leader know resource dynamics?	Yes or no on group level, once per game
Is the leader convinced about the resource dynamics?	Yes or no on group level, once per game
Do others follow due to lack of knowledge?	Yes or no on group level, once per game
Is the leader leading because he/she is convincing?	Yes or no on group level, once per game
Did they stick to the agreement?	Yes or no on group level, once per game
Reasons for not reaching optimal	Cheating, lack of knowledge, lack of communication, precaution, other
Talking about changing strategy in round...	Round number
Talking about the end?	Yes or no on group level, once per game
Estimating the end?	Yes or no on group level, once per game
Does anyone cheat?	Yes or no on group level, once per game
In which round does the cheating occur first?	Round number
Was the cheating on purpose?	Yes or no on group level, once per game
Do the others realize the cheatings?	Yes or no on group level, once per game

Appendix 4 – Poster

Figure 5: English poster for advertising

Appendix 5 – Poster Swedish

Figure 6: Swedish poster for advertising

Appendix 6 – Website

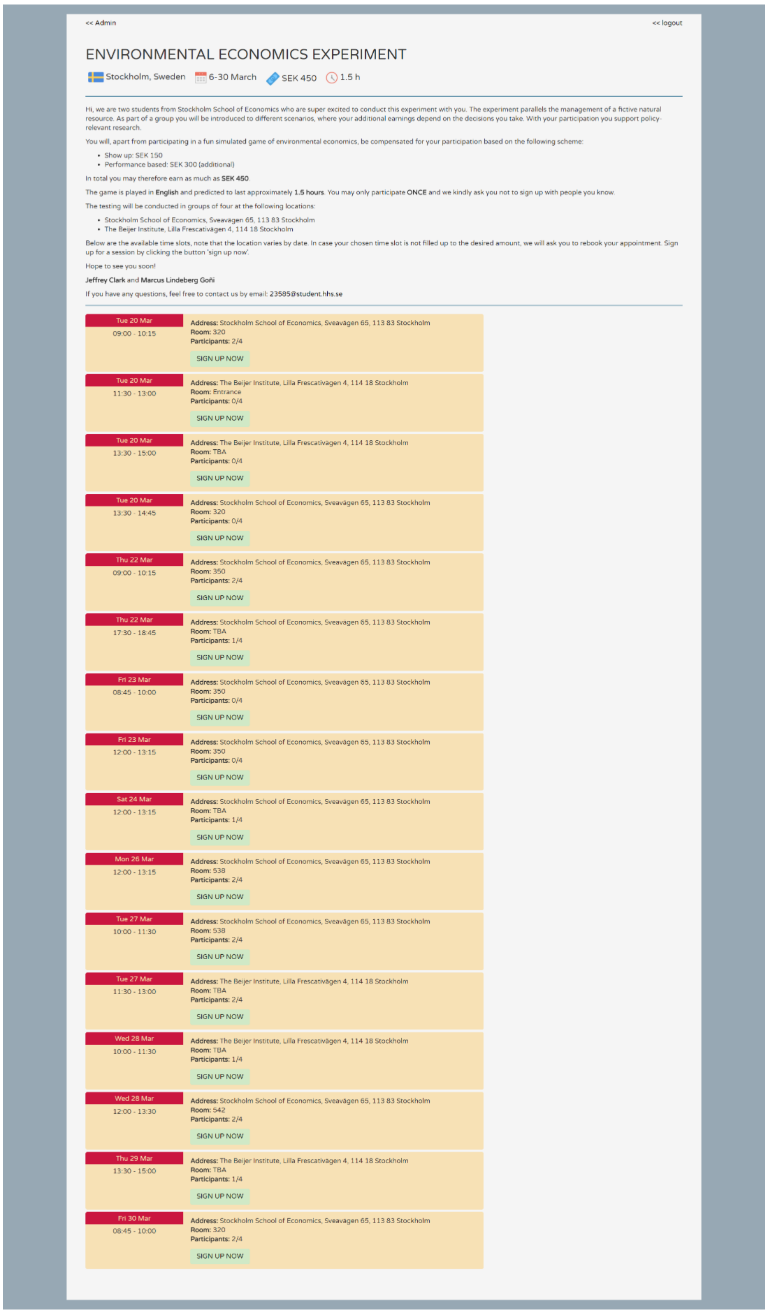

Figure 7: Website for signing up to the experiment

Appendix 7 – Participant protocol

Please maintain the protocol folded during the whole game

Table 19: Participant protocol table

Participant number:

Year	Catch	Year	Catch	Year	Catch
2018		2031		2044	
2019		2032		2045	
2020		2033		2046	
2021		2034		2047	
2022		2035		2048	
2023		2036		2049	
2024		2037		2050	
2025		2038		2051	
2026		2039		2052	
2027		2040		2053	
2028		2041		2054	
2029		2042		2055	
2030		2043		2056	
Test round 1:		Test round 2:		Test round 3:	

Appendix 8 – Participant questionnaire

* Compulsory

1. Participant code (please ask your experiment leader)*

2. Gender*
   - Female
   - Male
   - Other
   - Prefer not to say
3. Age*

4. Nationality*
   - Sweden
   - Other
5. If other nationality, please indicate which.

6. Education (currently enrolled)*
   - No formal education
   - Primary school (högstadiet)
   - Secondary school (gymnasium)
   - Bachelor degree
   - Master degree
   - Higher than Master degree
   - Not currently enrolled student
7. Current university
   - Stockholm University
   - KTH
   - Stockholm School of Economics

- Karolinska Institute
- None of the above
- Not currently enrolled

8. How many semesters (terminer) have you completed of full time academic studies?*

9. Your current estimated monthly income (in kr)*

10. The money I earn from the experiment is a substantial contribution to my monthly budget.*

Strongly disagreee	1	2	3	4	5	Strongly agree

11. Did you know any group member from before?*
    - Yes
    - No

12. If yes, how many group members did you know from before and how well did you know them?

13. Have you taken part in a similar experiment before?*
    - Yes
    - No

14. How did you get informed about the experiment?*
    - Posters
    - Facebook
    - Portal news
    - ”Inspring”
    - Friend recommended it
    - Other website
    - Through an experiment leader

15. If your participant code ENDS with a C, D or U, what kind of change of the experimental setting did you personally anticipate?

16. Right before the experiment ended, I expected it to last for at least one more round?*

Strongly disagreee	1	2	3	4	5	Strongly agree

17. Right before the experiment ended, for how many more rounds did you expect the experiment to continue?*

   - No more round
   - 1–3 more rounds
   - 4–6 more rounds
   - 7–9 more rounds
   - More than 10 more rounds

18. Assume you would have known in which round the experiment ends, would you have harvested the remaining resource units in the last round?*

   - Yes
   - No

19. I got a good understanding about how the resource changed over time.*

Strongly disagreee	1	2	3	4	5	Strongly agree

20. The instructions and explanations by the experiment leader alone provided me with enough information to understand the relation between the resource stock size and our harvest decisions.*

Strongly disagreee	1	2	3	4	5	Strongly agree

21. It was the group discussion that helped me understand the relation.*

Strongly disagreee	1	2	3	4	5	Strongly agree

22. My understanding of that relation improved during the course of the experiment.*

Strongly disagreee	1	2	3	4	5	Strongly agree

23. Our group managed to cooperate.*

Strongly disagreee	1	2	3	4	5	Strongly agree

24. If your participant code ENDS wit a C or D, the change in resource regeneration increased the group's cooperation.

Strongly disagreee	1	2	3	4	5	Strongly agree

25. If your participant code ENDS wit a C or D, the uncertainty made me harvest less, or influence the group to harvest less.

Strongly disagreee	1	2	3	4	5	Strongly agree

26. The communication in our group was effective. We reached agreements.*

Strongly disagreee	1	2	3	4	5	Strongly agree

27. There was a leader of discussion in our group.*

Strongly disagreee	1	2	3	4	5	Strongly agree

28. was the leader of the discussion in our group.*

Strongly disagreee	1	2	3	4	5	Strongly agree

29. There was a high level of trust in our group.*

Strongly disagreee	1	2	3	4	5	Strongly agree

30. Fairness played a role in my decision-making.*

Strongly disagreee	1	2	3	4	5	Strongly agree

31. We shared the harvest equally.*

Strongly disagreee	1	2	3	4	5	Strongly agree

32. I cheated and dit not follow the cooperative agreements (if no agreement, skip question)

Strongly disagreee	1	2	3	4	5	Strongly agree

33. While taking my decisions, I took previous decisions of my group members into account.*

Strongly disagreee	1	2	3	4	5	Strongly agree

34. While taking my decisions, I took into account whether or not they affect the earnings of my group members.*

Strongly disagreee	1	2	3	4	5	Strongly agree

35. If you did NOT communicate/take part in the group discussion – why? (You can tick several options.)
    - Out of shyness
    - Lack of knowledge
    - Language barriers
    - No need to communicate
    - Other reason

36. Generally speaking, I only trust people that I have known for a while.*

Strongly disagreee	1	2	3	4	5	Strongly agree

37. Generally speaking, there are only a few people I can trust completely.*

Strongly disagreee	1	2	3	4	5	Strongly agree

38. Generally speaking, I think of myself as someone that can be trusted.*

Strongly disagreee	1	2	3	4	5	Strongly agree

39. Generally speaking, I express my opinion and thoughts openly and feel comfortable in discussions.*

Strongly disagreee	1	2	3	4	5	Strongly agree

40. Generally speaking, I enjoy working in teams.*

Strongly disagreee	1	2	3	4	5	Strongly agree

41. I am happy with the amount I earned.*

Strongly disagreee	1	2	3	4	5	Strongly agree

42. Other comments