Economic Essays on Cooperation in Environmental Decisions

Dissertation
zur Erlangung des akademischen Grades
Doctor Rerum Politicarum

an der
Fakultät für Wirtschafts- und Sozialwissenschaften der
Ruprecht-Karls-Universität Heidelberg

vorgelegt von
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Heidelberg, August 2023

Acknowledgement

In the past four years many people have accompanied me while working on this dissertation. I would like to thank all of them and there are a couple of people to whom I am especially grateful.

Stefan, thank you for taking me as a doctoral student. You gave me the opportunity to create my own ideas and guided me through implementing those ideas successfully in research projects. I am very grateful for having the freedom to fit my work to my circumstances.

Florian, thank you for agreeing to serve as a referee for my thesis. I would also like to thank Jale Tosun for agreeing to be part of my PhD committee.

Christoph, Manu, Tamas, David, you were not only my colleagues, but went with me through the last couple of years. Thank you for all the talks, discussions, and (maybe most importantly) the lunch-breaks that we spent together.

I would like to thank all my friends and family for always being there for me. Although I can not mention all of you I am extremely grateful to you! You always gave me motivation and strength when I needed it. I would like to give Wolfgang Hoppe a special mentioning; thank you for the many things that I could learn from you.

Lucy, without you I would not be where I am today. You always believed in me when I did not. Thank you for your invaluable support!

Contents

Chapter 1

Introduction

The decisions that we make today determine the state of the environment in the far future. We are currently on a path that will very likely lead to a strong decline in environmental quality over the next years and centuries: global temperatures are rising as a consequence of past and current greenhouse gas emissions (IPCC, 2023), biodiversity is decreasing due to land conversion (Semenchuk et al., 2022), and we continue polluting our oceans (Landrigan et al., 2020). To leave this path of environmental degradation and reach long-term environmental stability, different (groups of) decision makers have to cooperate with each other by making sustainable decisions today, potentially forgoing short-term profits. Although we can observe many unsustainable decisions made in everyday life people seem to care about long-term environmental outcomes. However, decision makers' long-run outcomes may depend on both solving the within-group cooperation problem, and the cooperation outcome of other groups. I distinguish two cases for such between-group linkages. First, groups may act sequentially, and earlier groups need to anticipate later groups' behaviour. Second, groups may act contemporaneously and in principal independently, but are linked via the long-run effects of all groups' actions on a joint environmental outcome. Such groups can be, for example, associations of local farmers, a country's inhabitants, or members of a generation. Underlying this framework is one key assumption: Agents care about long-term environmental outcomes, beyond their own life span and the life span of their direct descendants. This assumption will be the topic of the first part of my dissertation. In the second and third part, I focus on cooperation problems in the presence of potential long-term benefits from cooperation, in which both contemporaneous and intertemporal perspectives are jointly relevant to the decision makers.

To sustain a renewable resource (e.g., a forest) and achieve long-term stability of an environmental outcome (e.g., the climate or an ecosystem), different decision makers have to cooperate with each other by not extracting too much from the resource. In the absence of long-term preferences and political instruments individual actions can lead to overextraction of a resource jointly used by a group of individual decision makers (often referred to as the "tragedy of the commons", see e.g. Hardin, 1968; Ostrom, 2011). If we consider environmental stability in the long-run, for example, the goal of a 1.5 °C warming, or a stable local ecosystem, cooperation within a certain group of decision makers is only one part of the situation, as the long-term development of an environmental outcome is determined by both, a group's own actions, and different other groups in the present and in the future. Hence, the utility that people receive from the environment depends not only on decisions about their own (respective the own group's) usage of the environmental resource (e.g., harvesting timber from a forest), but it is also affected by decisions made by other players that can act contemporaneously or at different points in time.

There are different channels through which an intertemporal link between groups can emerge. On the one hand, if previous groups behaved unsustainably, members of current and succeeding groups can consume less and receive lower utility, as the respective environmental resource lost stability already in the short-run. On the other hand, the long-term survival of a resource or an environmental good matters for many individuals due to either an intrinsic valuation of the mere existence of the resource (even after one's own lifespan), or due to altruistic utility that is generated by the benefit of the environmental good for future generations (Andreoni, 1990; Layton and Levine, 2003; Gerlagh and Michielsen, 2015). Thus, people may be willing to accept lower consumption in the present to attain certain environmental goals in the long-run. However, the effort put into reaching these goals by one group can be undermined by an uncooperative succeeding group that can use the resource in the future (e.g., a future generation can destroy a previously preserved ecosystem).

The same is true if we consider a situation, where the long-term outcome depends not only on decisions made within one current group and other future groups, but where long-run benefits of within-group cooperation can only accrue, if other contemporaneous groups are cooperative as well (e.g., if the survival of an endangered species depends on forest-conservation in different neighbouring countries). The long-term benefits (e.g., the survival of a species) can outweigh the additional short-term profits that can be achieved by overextraction compared to a sustainable usage (e.g., logging the entire forest instead of a sustainable timber extraction). In this case, there are strong incentives for all decision makers to cooperate and extract sustainably. However, if other contemporary groups do not act sustainably, long-term benefits will not be attainable. As a consequence, there are few incentives for individuals to extract sustainably, because long-term benefits can not accrue anyway, independently of a decision maker's own behaviour. In this situation, within-group cooperation will fail, as decision makers aim for short-term profits because, due to the behaviour of other groups, long-term incentives to sustain are not strong enough. That is, otherwise independent contemporary groups are linked with each other through their effect on a shared long-run environmental outcome, and the subsequent effect on within-group incentives and trade-off between short- and long-run benefits.

To the best of my knowledge, and despite its empirical relevance, there is little research yet focusing on cooperation within groups when benefits depend on other groups' decisions (future or contemporaneous), that are linked by a preference for long-term stability of a resource. Because such situations abound in the real world, a well-founded environmental policy needs a good understanding of the mechanisms that affect cooperation and thus sustainability under these conditions. Indeed, there is related experimental work, assuming that one group's wellbeing depends on decisions made in other groups, building either on (*i*) intergenerational experiments, or (*ii*) multilevel public goods games. In intergenerational experiments, groups can extract from a resource (or invest in a public good), which will be available for other future groups. Hence, if current groups behave unsustainably, future groups cannot generate utility (Chermak and Krause, 2002; Fischer et al., 2004). When investigating whether an intergenerational link between groups favours or hinders cooperation, studies came to mixed results: while some experiments found higher rates of cooperation in current groups when costs of uncooperative behaviour are passed on to future groups (Spiller and Bolle, 2016; Grolleau et al., 2016), others found the opposite to be true (Jacquet et al., 2013; Sherstyuk et al., 2016; Ponte et al., 2017). Cooperation of present decision makers may be fostered by making the existence of future generations more salient, be it through the presence of either real members of future generations during the decision process (Fornwagner and Hauser, 2022), or a representative of an "imaginary future generation" in negotiations (Kamijo et al., 2017). Intergenerational cooperation (and hence sustainability) was shown to be improved by implementing costly commitment devices or reducing uncertainty about tipping points (Dengler et al., 2018), or by the possibility of within-group punishment (Lohse and Waichman, 2020). If a group's majority wants to cooperate and extract sustainably from a resource that will be used by future groups as well, voting on the group's joint extraction has been found to increase sustainability, as the cooperative majority could overrule the defective minority that would have extracted too much from the resource in absence of the voting (Hauser et al., 2014). Böhm et al. (2020) showed that nudges can be used to improve intergenerational cooperation. In their experiment, participants could contribute to a short-term or a long-term public good, where the former was cheaper than the later, but investments in the long-term public good where also to the benefit of future groups.

While studies on intergenerational cooperation provide insights relevant for decisions that affect the wellbeing of future generations, they do not consider that people may intrinsically value the environment and environmental stability in the long-run. This is important, because in the latter case, a future generation is not just the recipient of altruistic behaviour by current generations, but may also be a problem for long-run stability. This is the case if one future generation does not behave cooperatively, exploiting resources, and spoiling earlier generations' effort to achieve long-run environmental stability through sustainable behaviour, forgoing immediate benefits. At present, there are only two studies that explicitly model those long-term preferences (Chaudhuri, 2011 and Dengler et al., 2018). However, there is no research yet on the case where long-term benefits of intergenerational cooperation are linked to within-group cooperation. As argued above, such links between contemporaneous and intergenerational aspects are important in practice, and incorporating long-term preferences in within-group cooperation will thus provide insights on cooperation failure.

The second area in the literature that is closely related to the research presented in this thesis focuses on multilevel public goods. In those studies, one choice option (a "local public good") benefits only members of a player's own group, while investments in the other option (the "global public good") benefit members of other groups as well. Although the per capita returns from investments in the global option are smaller than from the local option, the social optimum is reached when all players invest in the global option because it affects more people. However, coordination is more difficult in the larger global group. In experimental studies on multilevel public goods, most players prefer investing in the local option over the global option, and the social optimum is often not achieved (e.g., Buchan et al., 2009; Gallier et al., 2019). Experiments on multilevel public goods are related to the research presented in this dissertation, as players' utility depends on both decisions made by members of the own group and other groups' decisions. However, in previous studies, decisions made by members of other groups (and beliefs about it) do not affect incentives for within-group cooperation (in the local group). Such influences on local cooperation via the temporal link with other groups is the essence of the perspective taken in my dissertation.

The aim of this thesis is first to get an insight into the preferences people hold for the far future. Second, I aim to give a better understanding of within-group cooperation dynamics in situations where (*i*) long-term stability can only be reached through sustainable behaviour (i.e., cooperation) within different groups, (*ii*) all actors in all groups have an interest in the long-term existence and stability of the respective environmental good, and (*iii*) cooperation and thus sustainability is feasible and an equilibrium.

The dissertation takes three steps. In a first step I elicit people's preferences for the far future. In the second step, I will incorporate the intertemporal linkage between groups, while the third step investigates whether within-group cooperation is (negatively) affected if benefits from cooperation depend on decisions made in other contemporaneous groups as well. In the next paragraphs I want to give an overview of each chapter of the dissertation.

In the first research paper (Chapter 2 of this dissertation) I aim to investigate people's preferences for the very far future. Together with my co-author Stefan Trautmann I run an online survey experiment with 1201 participants from the United Kingdom to identify the magnitude and determinants of households' willingness to pay (WTP) for a stable environment. This research project is the first to elicit WTP for environmental goods with benefits that accrue far beyond people's own lifespan and the effect of the presence or absence of a cooperation problem on this WTP.

We ask participants of the experiment to indicate which fraction of their income they are willing to give up in order to keep the environment in general stable, including the climate, biodiversity, and other aspects. There are four treatments that differ along two dimensions: *i*) the time-horizon of the decision problem (short-run versus long-run), and *ii*) whether there is a cooperation dilemma due to uncertainty about others' decisions. We use a between-subject design and, hence, subjects are either assigned to the short-run treatment with uncertainty, the short-run treatment without uncertainty, the long-run treatment with uncertainty, or the long-run treatment without uncertainty. In the two treatments with the short-run time-horizon subjects are asked to indicate their WTP to keep the environment stable over the next few years and decades, while the two long-run treatments elicit WTP for a stable environment in the next centuries. In the latter case we mention explicitly that most of the benefits of a stable environment will accrue at a later point in time, after the respondent's own lifespan and the lifespan of the respondent's kin.

To elicit people's WTP in the absence of a cooperation problem we ask in the two treatments without uncertainty for the fraction that a respondent is willing to give up under two assumptions. First, everybody giving up this fraction would be sufficient to keep the environment stable in the respective time-horizon, and second, everybody agreed on and committed to giving up this share. This second assumption ensures that there is no possibility for free-riding or other strategic considerations and, hence, there is no cooperation problem. In the two treatments with uncertainty there is no such assumption and participants face a cooperation problem due to the uncertainty about others' WTP. These two treatments include an elicitation of participants' belief about their peers' WTP.

The resulting data suggest that people are willing to give up a substantial fraction of their income for a stable environment, with a WTP exceeding 8% of income in all four treatments. There is no significant difference in the willingness to contribute for environmental stability in the short-run or in the very long-run. However, the presence of a cooperation problem has an effect on WTP as people state a significantly lower WTP when facing a cooperation problem. Together with our data on people's belief we find that most subjects can be classified as pessimistic conditional cooperaters who base their own decision on their subjective belief about others' WTP but at the same time significantly underestimate the fraction that their peers are willing to give up.

After having established the wide spread prevalence of long-term preferences I induce these preferences in the experiment of the second research project, presented in Chapter 3 of this dissertation. I focus on the intertemporal cooperation dilemma that decision makers face if long-term preferences exist but the stability of the respective environmental resource is potentially endangered by future groups of decision makers. Using a lab experiment I investigate whether the existence of a future group that can affect a current group's payoff reduces within-group cooperation in current groups.

The experiment is based on a resource extraction game with a renewable resource. Each group is endowed with an initial resource and the group's members can extract over multiple periods from this resource for individual consumption. The main part of the experiment consists of three phases and each phase consists of multiple periods. I use a between-subject design and implement two treatments. In one of the two treatments control over the resource is switched between groups. While in phase 1 some group A holds control over the resource, it gets handed over to another group (here referred to as group B) in phase 2. After phase 2 group B's leftover of the resource is handed back again to group A to use it in phase 3. I am mainly interested in groups' behaviour in phase 1: phase 3 induces the long-term preferences and phase 2 implements the intertemporal cooperation problem. If group B exhausts the resource in phase 2, group A has no incentive to extract sustainably in the first phase. However, because of the (induced) long-term preferences, it is socially optimal to always extract sustainably. In the second treatment there is no switch in control over the resource and group A keeps the control in all three phases. The comparison of the two treatments gives a hint about the effect of the existence of an intertemporal cooperation problem on present decisions. Importantly, sustainable extraction by all players throughout all three phases is an equilibrium in both treatments. However, although the intertemporal linkage between groups does not change the theoretical predictions and the cooperative and sustainable equilibrium is still feasible, groups in the treatment with switching control over the resource fail significantly more often to cooperate and exhaust their resource already by the end of phase 1.

While the research presented in Chapter 3 focuses on the cooperation problem if groups act sequentially, I consider an intratemporal linkage between groups acting at the same time in the work presented in Chapter 4 of this thesis. Multiple contemporaneous groups act independently in their short-run decisions but are linked via a common long-term benefit that can only be achieved if all groups act sustainably. In this paper, I aim to study cooperation within a group if long-term benefits of cooperation depend on other contemporaneous groups' actions as well.

If decision makers hold preferences for the long-term stability of an environmental resource (e.g., a local forest or the climate) behaving sustainable can be a within-group equilibirum as players are willing to forgo some consumption in the present if this helps to enhance long-term environmental quality. However, in many cases the long-term outcome is determined not only by a single decision maker or one group, but by decisions made in various contemporaneous groups. If the long-term environmental outcome is (perceived to be) endangered through actions taken in other groups, the incentives for sustainable decisions (i.e., cooperation) within a group will decrease and ultimately the cooperative within-group equilibrium can break down. I will call this point the *political tipping point* as reaching this point implies a sudden and substantial change in incentives and the set of within-group equilibria.

To inquire the effect of this spillover between groups in long-term consequences of (un-)sustainable decisions I design a novel theoretical model and implement this model in a lab experiment. Through the choice of parameters, I can vary the magnitude of spillover between groups and, thus, the location of the political tipping point, i.e., the level of cooperation in the other groups that is inevitable for the existence of the sustainable within-group equilibrium. Although I can not find a monotonic relationship between the magnitude of between-group spillover and the level of within-group cooperation, I find failure of cooperation if between-group spillover is moderate. Furthermore, there is a significant effect of reaching the political tipping point. In line with the implications arising from the model, within-group cooperation significantly decreases if the political tipping point is surpassed and incentives to act unsustainable outweigh incentives to cooperate.

In Chapter 5 I give an overall conclusion of the three research projects presented in chapters 2 to 4. I also give some policy implications that evolve from this research.

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Chapter 2

Preferences for the Far Future

Abstract. When it comes to sustainable behaviour, do people care predominantly about short- and medium-run benefits to themselves and maybe their kin, or do they also intrinsically value the very long-run outcomes for the planet? For a large population sample, we show that people substantially value the environment intrinsically, i.e., even after their own and their kin's lifespan. Long-run environmental benefits not experienced by the respondent elicit similar willingness to pay as mere short-run benefits experienced by the respondent. However, adding a cooperation problem via uncertainty about other people's preferences significantly decreases participants' willingness to pay. Our data suggest that the empirically observed failure to act sustainable is not due to low concern for the environment, but rather due to the multitude of intra- and intergenerational cooperation problems.[1]

[1]This chapter is joint work with Stefan Trautmann. An earlier version of this chapter has been published as a working paper as: Steinke, Marek, and Trautmann, Stefan T (2021): Preferences for the far future. AWI Discussion Paper 706.

2.1 Introduction

Human activity over the past centuries has led to substantial changes in our natural environment: the climate is changing faster than expected; we see a severe loss of biodiversity; there is increasing pollution of oceans (IPCC, 2023). Observations from everyday life may suggest that people often care about, and are willing to pay for, environmental stability: politicians, on behalf of their electorate, spend time and money on negotiating international agreements on protecting the climate; consumers accept higher costs when buying ecologically produced food; travellers and organizations compensate their emissions from flying. Importantly, absent an intrinsic preference for the very long-run stability of the environment, it is not clear that these activities are beneficial for today's consumers, compared to maximizing their own and their direct descendants' financial resources instead, to cope best with the expected changes (Purdy 2019). However, despite the apparent willingness to protect the environment, long-term environmental stability is endangered due to unsustainable decisions that lead to further deforestation, pollution, and emissions. Given the looming failure to preserve long-term stability, we ask whether poor environmental outcomes are caused (*i*) by a coordination failure of decision-makers (e.g., consumers, politicians) who in principle value the environment in the long-run, but fail to successfully cooperate on their jointly preferred outcome. Or (*ii*) by a lack of sufficiently large and wide-spread willingness to pay (WTP) for environmental stability in the far future, where current consumers will not directly benefit from it. I.e., do large parts of the population sufficiently care about long-run environmental stability to give up some of todays' economic wealth in order to save the environment? To answer this question, our study takes two approaches: first, we elicit whether people value environmental stability only if they will enjoy the benefits of better environmental conditions themselves (in the next decades), or value it intrinsically, apart from any use value, and are willing to pay for its provision, even if benefits do not accrue until the far future, beyond their own and their family's lifespan (in the next centuries). Second, we aim to test for the potential effects of an underlying cooperation problem in the provision of environmental goods. Specifically, how WTP for environmental goods is affected by the presence of uncertainty about others' preferences and, hence, a cooperation problem, compared to a situation without the threat of cooperation failure.

Previous studies on environmental, non-market goods reveal positive WTPs for various goods, even if they do not directly benefit the decision makers (e.g., through usage of the respective good or benefit, e.g., Loomis and White, 1996). Programs for the reduction of greenhouse gases will often induce both short- and long-run benefits, potentially explaining parts of the large variation in observed WTP (see also Nemet and Johnson, 2010). For example, two thirds of the lab-in-the-field experimental participants in Fornwagner and Hauser (2022) invested their entire endowment of EUR 69 in a CO2-offsetting program planting near-city trees. The high WTP for CO2-offsetting in this study may derive from respondents valuing the expected climatic effects of the induced CO2-offsetting (long-run stability), as well as from the potential recreational value of trees close to the city (short-run experienced benefits). In contrast, studies on people's valuation for the retirement of CO2, which presumably induces only medium- and long-run effects, found much lower values: Brouwer et al. (2008) report a WTP of EUR 25 per ton of CO2 retired, Löschel et al. (2013) report a WTP of EUR 12, and Diederich and Goeschl (2014) report a mere average WTP of EUR 6.30, with the median participant willing to pay only EUR 0.30. While these studies suggest that long-run preferences for environmental stability exist but may not be very strong and prevalent across the population, the observed valuations cannot necessarily be taken at face value, because they are also affected by cooperation problems and uncertainty about other people's preferences. For example, Diederich and Goeschl (2014) used the European Emissions Trading System to elicit participants' WTP for a certificate for one ton of CO2. If people do not believe that individually buying some certificates sufficiently reduces CO2 emissions in practice, they will naturally indicate a very low WTP, irrespective of how much they really value climate stability. That said, some studies have found positive valuations even in the presence of such policy uncertainty and long-run outcomes (Layton and Levine, 2003).

In general, most environmental goods show aspects of public goods adding complication to the elicitation of intrinsic valuations. People may condition their stated WTP on their belief about others' WTP: they might expect free-riding by others and, hence, give less, or free-ride themselves. Liebe et al. (2011) showed that people are pessimistic about other's WTP for environmental goods and that there is a high discrepancy between average stated WTP and people's average belief about other's WTP. If WTP is elicited in the presence of a cooperation problem (which is always the case in decisions about real contributions to voluntary climate action), the resulting valuations will be smaller than in the absence of a cooperation problem, if people base their decision on pessimistic beliefs about others' WTP (Bardsley and Moffatt, 2007). This effect has recently been demonstrated in a study by Andre et al. (2021). US Participants in a WTP study on fighting climate change strongly underestimated both the fraction of other participants who try to fight climate change, and the fraction of participants who think that the US should try to fight climate change. Correcting these misperceptions by informing about the true prevailing norms significantly increased participants' WTP. The result is consistent with (*i*) the more general effect of shifting social norms on social decisions (Goeschl et al., 2018), and (*ii*) the finding that people tend to misperceive social norms by underestimating other's support for more climate friendly policies (Sparkman et al., 2022).

Our survey experiment is closely related to experimental work on the provision of intergenerational public goods, where decisions made by members of a current group affect members of future groups. When the costs of uncooperative behaviour (e.g., lower investments in an intergenerational public good) are passed on to future groups and do not affect the current group of decision makers, some experiments found cooperation to increase (Grolleau et al., 2016, Spiller and Bolle, 2016), while others found the opposite behaviour (Jacquet et al., 2013, Sherstyuk et al., 2016, Ponte et al., 2017). Cooperation may be improved by the introduction of policy mechanisms such as voting

(Hauser et al., 2014) or punishment (Lohse and Waichman, 2020): groups using such mechanisms were able to overcome the cooperation problem more often and were more successful in reaching the sustainable outcome. In line with our above argument for preferences for the far future, studies found that a personal link to future decision makers increased cooperation, compared to situations where there was no such link. This effect has been shown for the presence of a hypothetical representative of future generations in negotiations or mere perspective-taking (Kamijo et al., 2017, Shahen et al., 2021), as well as for the presence of a real representative of the next generation in the form of the decision maker's own child (Fornwagner and Hauser, 2022). We test for the effect of this link and investigate differences in WTP for the far future between parents and non-parents.

In the present study, we aim to probe the prevalence of intrinsic preferences for long-run ecological stability in the presence of measurement problems due to short-run benefits, cooperation problems, and uncertainty about others' values. To this end, we measure WTP both, in the presence and in the absence of a cooperation problem, i.e., with and without uncertainty about the amount others are going to pay when committing to own WTP (Bardsley et al., 2022). The latter case can be interpreted in terms of policies that secure contributions by all citizens. This makes asking for the WTP equivalent to asking for the valuation of the environmental public good, instead of a strategic individual contribution to a pure public good. We will not elicit people's WTP for a single environmental good (e.g., a species) or a certain policy (e.g., planting trees). The focus of this study is on people's valuation and maximum WTP for environmental stability in general, including climate stability, pollution, and biodiversity: we believe that from a long-run perspective, it makes less sense to consider stability in only specific domains allowing for poor outcomes in others. From the vantage point of the decision maker it is unclear, for example, how to value a stable climate if at the same time reduced biodiversity or severe pollution threaten human societies (Diaz et al., 2006, IPBES, 2017). Eliciting WTP for broad ecological stability directly also reduces bias due to beliefs about the effectiveness or any side-effects of specific policies. To gauge the relative importance of short-run use values and long-run intrinsic benefits, we elicit WTP both for benefits of the investment in the environmental good that will accrue within the consumer's life-span, and for those that accrue only in the far future, after the decision maker's own lifespan, and even after the lifespan of all her friends and family.

In the next section we present our survey design and provide details on the WTP measurement. The following section gives the results. Our findings support the view that a substantial share of the population holds economically relevant intrinsic preferences for the very long-run stability of the environment. However, uncertainty in the cooperation problem and pessimism about others' preferences reduce valuations, and lead to a significant portion of the population not willing to contribute any meaningful share of their income. The final section discusses theoretical and policy implications.

2.2 Survey Design

We used an online survey experiment to elicit stated preferences for the stability of the environment in the general population. The experiment was programmed in oTree (Chen et al., 2016), and we recruited participants via the online platform Prolific. The study was preregistered on aspredicted.org (#51473 and #52857).

The main survey consisted of three or four parts, depending on the respective treatment (see below for details). The first part of the survey elicited participants' views on climate change. The second part elicited stated-preference indications of how strongly participants care for the environment over different time-horizons. These two parts were identical for all four treatments. Treatments differed for the third part, where we elicited WTP for an overall environmental stability (climate, biodiversity, pollution). The treatments differed according to two dimensions: (*i*) absence / presence of a cooperation problem, and (*ii*) short-run / very long-run time-horizon. The two treatments with a cooperation problem included a fourth part, where we asked participants for their beliefs about others' WTP. The main survey was followed by a short questionnaire where participants indicated the number of children and grandchildren they have (if any). Details about each part follow hereafter (see the Appendix for instructions and wording of the questions).

In the first part of the survey, participants answered three questions about climate change: (*i*) whether they think that the climate is changing, (*ii*) if they believe that climate change is happening, whether it is caused by human activity or rather by natural processes, and (*iii*) whether they believe that technologies will evolve in the future, that allow humans to regulate the climate. Note that questions (*i*) and (*ii*) were taken from the European Social Survey.

The second part of the survey asked participants how strongly they care about the state of the environment over different time horizons (short-term, long-term, and very long-term), using a verbal stated-preference format. In particular, on three separate screens they were asked how much they agree with the following statements *"I care about the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) in the next ten years"* (short-run), *"I care about the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) in the next decades, even after my own lifespan"* (long-run), and *"I care about the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) a few centuries from now, after my own lifespan and the lifespan of all my friends, family, and their descendants."* (very long-run). The possible answers ranged from 1 (*"Strongly disagree"*) to 5 (*"Strongly agree"*), so a higher number indicates a higher concern for the environment in the respective time-scale.

The second part of the survey allows us to find differences in the concern of a stable environment that stem from different time-horizons and to investigate whether people care intrinsically, or only seek for stability if they (or at least their descendants or friends) benefit directly from it. As direct benefits to the respondent and their kin decrease with longer horizons, we expect the degree of concern for the environment to decrease with the time-horizon. A higher consideration of the environment during the own lifespan than after the own lifespan would be consistent with the results of Jacquet et al. (2013), who found lowest climate action if benefits were passed on to future generations. As making salient people's connection to future generations seems to have a positive effect on willingness to invest (Kamijo et al., 2017, Fornwagner and Hauser, 2022), we expect the degree of concern to be higher in the long-run (with link to future generation) than in the very long-run (without link to beneficiaries), as in the latter case we explicitly asked for the valuation after the participant's and all her descendants' lifespan. If a person cares strongly about environmental stability in the very long-run, we expect her also to care about the environment in the short-run and to state a high concern for all time-scales. However, someone who values the environment intrinsically but discounts future benefits, would care strongly about environmental stability in the short-run, care substantially less for the environment after her own lifespan, and even less after the lifespan of all her friends and family. This behaviour would lead to a high degree of agreement for the first statement (short-run), a lower agreement for the second (long-run), and the lowest agreement for the third statement (very long-tun). Hence, we formulate our first hypothesis:

> *Hypothesis I: People state a higher degree of concern of the environment for the short-run than for the long-run, and a higher degree of concern for the long-run than for the very long-run.*

The third part of the survey used a titration method to elicit participants' monetary valuations in terms of maximum WTP for securing a state of general environmental stability. To minimize the effect of income on stated WTP, WTP was measured as the (maximum) fraction of net income that participants would be willing to give up in order to save the environment, using a choice-based titration task. In a first step of the elicitation, participants were asked whether (under two assumptions described below) they would be willing to give up 10% of their net-income to keep the environment stable. If they answered "Yes", the fraction asked for increased in the next step of the elicitation; it decreased if participants indicated "No" (see Figure 2.1 for the steps of the titration). The titration included four steps and, hence, resulted into one out of 16 possible ranges. All participants went through all four steps and did not have the possibility of finishing the survey faster by accepting the first best option offered to them. After the elicitation, participants were informed about the resulting range (e.g., *"between 3.5 and 5%"* of net-income) and what this range means in absolute terms for each GBP 1000 they earn. Participants than could confirm or reconsider the resulting range. If they did not confirm the result, they could reconsider their WTP by choosing from a choice-list the range that represents their WTP. The list included the 16 possible ranges that resulted from our titration method. In the subsequent data analysis, we use participants' final WTP, i.e., values indicated after confirmation or potential reconsideration.

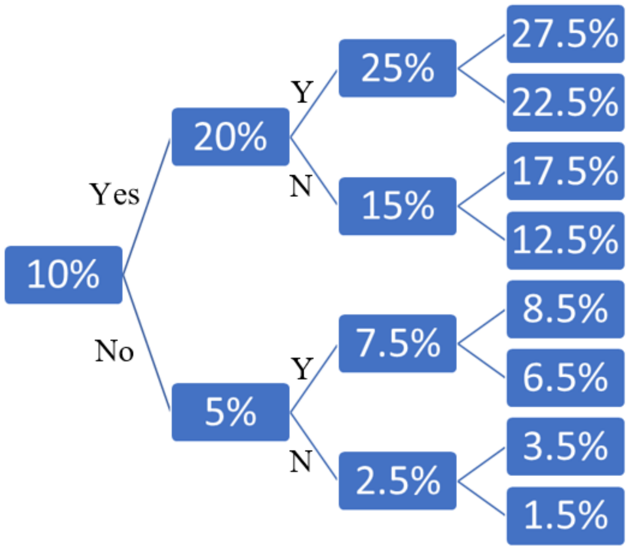
In the WTP valuation task, participants were asked to make two key assumptions: one concerning the time-horizon and one about the behaviour of other people. For each of the two dimensions, there were two possible formulations of the assumption, according to the treatment participants were randomly exposed to. Concerning the time-horizon, participants should assume *"that the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans)"* either could be *"kept stable only in the short-run, i.e., over the next few decades during your lifespan"* (decades condition), or could be *"kept stable in the long-run, i.e., over the next few centuries"* (centuries condition) if everybody were indeed giving up the share of their income asked for in the respective step of the titration. Additionally, participants in the *decades* conditions were told that many of the benefits of giving up this share would accrue in the next few years, while participants with the *centuries* condition were told that many of the benefits of giving up this share would accrue at a later time, after their own lifespan. Thus, using the choice-based titration task, we assess which fractions of net income participants are willing to give up under the important assumption that this will indeed allow for a stable environment in the defined time span (but see below for the role of the coordination problem).

The second assumption concerned uncertainty about others' willingness to pay. In the absence of a coordination problem, participants indicated their WTP assuming that *"everyone agreed on and committed to giving up this share"* (certainty condition). That is, participants indicated a maximum willingness to pay with the understanding that this is conditional on everybody else also forgoing this share, thus basically dictating the societal decision. In the treatment with a cooperation problem present, participants indicated their WTP assuming that *"When you make your commitment to give up this share, you do not know what share of their income others will give up"* (uncertainty condition). That is, participants indicated a maximum willingness to pay with the understanding that others may give more, or less. Importantly, in all conditions, we asked participants to assume that the state of the environment could be kept stable (in the respective time-scale) if everybody gave up the fraction under consideration (which can be interpreted as a reduction of overall GDP). Put differently, if everybody giving up $x\%$ of their income was enough to keep the state of the environment *in general* stable, would participants be willing to give up these $x\%$? However, only in the certainty condition was this latter requirement automatically fulfilled. Participants in the uncertainty condition faced a cooperation problem: the environment could be kept stable if everyone gave up the fraction under consideration, but one cannot be certain that everybody does. If not everybody contributes as stipulated, the benefits of contributing are uncertain.

Participants saw the task description with either the decades or the centuries assumption, and the certainty or the uncertainty assumption. Then they were asked, whether they would be willing to give up the displayed percentage (see Figure 2.1) under the stated assumptions.

The combination of the two dimensions (time-horizon and certainty) leads to four different treatments: *decades & certainty, decades & uncertainty, centuries & certainty*, and *centuries & uncertainty*. In a fourth part of the survey, participants of the two uncertainty treatments were asked about the fraction they believed others are willing to give up. They could directly indicate one range out of a list of the 16 ranges resulting from the titration method, that describes best their belief about others' WTP (see also Appendix Table 2.B.1 for the resulting ranges). As argued above, with uncertainty about others' contributions, beliefs about those contributions become relevant for people's

Figure 2.1: Titration Method



Notes: This figure was not shown to participants. Upper branches always indicate "Yes", lower branches indicate "No".

own willingness to contribute.

As it was explicitly mentioned that most of the benefits of the environmental stability that could be achieved would accrue after participants' and their kin's lifespan in the two *centuries* treatments, we expect them to be willing to give up less than participants in the *decades* treatments, who would directly benefit from their own investment. Following the results of Jacquet et al. (2013), we formulate our second hypothesis:

> *Hypothesis II: People in the two centuries conditions have a lower WTP than participants in the decades conditions.*

Hypothesis II is tested by comparing WTP for *centuries* and *decades* conditions. We also expect a difference between the *certainty* and the *uncertainty* conditions. In the *certainty* conditions it is guaranteed that everybody gives up the respective fraction. Hence, there is no cooperation problem between participants, i.e., no room for beliefs about other's WTP, strategic considerations, and no possibility of free-riding. However, participants in the *uncertainty* conditions face a cooperation problem. People may anticipate free-riding behaviour and have the possibility to free-ride themselves, which both imply a decreased WTP. Conditional cooperation with pessimistic beliefs also depresses WTP (Fischbacher and Gächter, 2010). This leads to our third hypothesis:

> *Hypothesis III: Participants in the uncertainty conditions state a lower WTP than participants in the certainty conditions.*

Anticipated free-riding of others could also lead to a higher WTP, as people might want to make up for lower contributions of others. However, as the survey is about global environmental stability, rather than about a small and restricted intervention, the contribution of a single individual is negligibly small and one higher investment cannot easily make up for lower investments of others. However, we can explicitly test the effect of anticipated free-riding using the data on beliefs that we collect in the fourth part of the survey (only in the two *uncertainty* conditions). Following the argument on conditional cooperation laid out above, and the finding that few people behave purely altruistically in cooperation contexts (Fischbacher, Gächter, and Fehr, 2001), we formulate our fourth hypothesis:

> *Hypothesis IV: Participants' own WTP is lower than or equal to their belief about others' WTP.*

2.3 Results

2.3.1 Sample

We conducted the experiment in November 2020 and collected data for a total of 1201 participants, who earned GBP 1.35 for completing the survey. We had 291 participants in the *decades & certainty* treatment, 310 in *centuries & certainty*, 281 in *decades & uncertainty*, and 319 in *centuries & uncertainty* (differences are due to the computerized random assignment of participants to a treatment). Our youngest participant was 18 and the oldest 81 years old, and participants were on average 35 years old. The average (and median) participant had an annual income of between GBP 30,000 and GBP 39,999. 66.28% of our sample were female, and 42.71% had 1 or more children. 5.08% had one or more grandchildren (see Appendix Table 2.B.2 for details).

2.3.2 Stated Concern for the Environment

The analysis of the data collected in the second part of the survey suggests that people care substantially for the environment for all three time-scales. The degree of concern was measured on a 5-point-scale, with 5 being the highest and 1 the lowest possible consideration of the environment in the respective time-scale. The mean stated concern was at 4.496, 4.415, and 4.163 for the short-, the long- and the very long-run, respectively. No participant indicated the lowest concern for the short-run statement. The median participant indicated a 5 for the short- and the long-run, and still a 4 for the very long-run, concerning the environmental situation in the far future, not only after the respondents own, but even after all her friends' and family's lifespan. This implies a significant intrinsic valuation of the environment, also if benefits of environmental stability will neither affect the respondent herself, nor her direct descendants. However, irrespective of the overall high concern for the environment at all time-scales, a comparison of the valuation in the short- and in the long-run shows that people are less concerned about the state of the environment in the latter case, where they are not affected themselves (Wilcoxon signed rank Test $p < 0.001$). Compared to the long-run, stated concern further decreases in the very long-run, when there are few or no links to the generations who will be affected by the future state of the environment ($p < 0.001$). Hence, although the degree of concern for the environment is high at all time-scales, it decreases for far-future consequences, in line with our Hypothesis I.

2.3.3 Willingness to Pay for Environmental Stability

Participants' answers to the statements in the second part of the survey indicate that they care about environmental stability in the near future, long term and also the very long term, the far future. We next study how these attitudes towards the environment translate into willingness to pay valuations for the preservation of a stable environment. Table 2.1 shows for each of the four treatments average WTP as a share of disposable net income. WTP for environmental stability is substantial in all four conditions, about 10% of income (see also Appendix Table 2.B.1 for the entire distribution of WTP). We observe no statistically significant differences between WTP for the decades and the centuries condition in either of the (un)certainty conditions. Thus, we do not find support for Hypothesis II. Consistent with the above-discussed high degree of concern for the very long-run, we observe substantial willingness to financially contribute to stability over centuries, beyond the own family's life span.

Table 2.1: WTP in the four Treatments as Fraction of Net-income

	Decades	Centuries	
Certainty	10%	9.927%	$p = 0.745$
Uncertainty	8.212%	8.382%	$p = 0.911$
	$p < 0.001$	$p = 0.003$	

Notes: WTP was measured as a range. For the analysis shown in the Table and presented in this section we took a conservative approach and used the lower bound of each range (and 1 for the lowest possible WTP) to not overestimate people's WTP. p-Values according to Mann-Whitney-U test.

However, we find significantly smaller WTP in the presence of a cooperation problem, for both time horizons. Not only is the average WTP lower, but also the fraction of respondents indicating a WTP lower than 1.5% of their income (our lowest possible category) is substantially larger. In the conditions with no uncertainty about others' contributions, 11.7% (*decades*) and 15.2% (*centuries*) of participants had a WTP below 1.5% of their income. This fraction increases to 20.3% (*decades*) and 24.5% (*centuries*) of participants in the conditions where others' contributions were uncertain. We observe that overall only 22.9% of all participants stated a WTP at one of the boundaries of our titration method (18% at the lower bound and 4.9% at the upper bound). This implies that the majority of participants changed their answer from one step of the titration to the next (instead always answering *"yes"* or *"no"*), which suggests that participants carefully considered the prices presented. And indeed, the fraction of participants at the lower bound differed between the *uncertainty* and the *certainty* conditions in the expected direction, i.e., being lower in the latter case.

The results are confirmed in a multivariate analysis. Table 2.2 shows the outcome of four regression models including different sets of covariates, and two dummy-variables for the *decades* and *uncertainty* conditions, respectively. *Decades* conditions are not significantly different from the *centuries* conditions, while the presence of uncertainty about others' contribution decreases respondents' WTP by roughly 1.5 percentage-points of income. This supports Hypothesis III, WTP is larger when there is no uncertainty about others' behaviour and, hence, no cooperation problem.

The multivariate analyses also indicate that WTP measures map positively on the stated consideration for the environment as indicated in Part I. They are also higher for those respondents who believe in climate change (in line with Reichl et al., 2021), and lower for those who think climate change is not human-made or that future technologies will emerge that will allow engineering the environment. Regarding demographics, we find that WTP decreases with age: older people are willing to give up less than younger people. Interestingly, respondents with children have lower WTP than non-parents. The effect is smaller if we include environmental attitudes (model 4), but a direct raw comparison of parents to non-parents shows significant differences as well (Mann-Whitney-U test $p < 0.001$). This result is not in line with our expectations. Fornwagner and Hauser (2022) show substantial WTP for parents, and we expected parents to have a higher WTP for long-term environmental goods due to their genetic link to future beneficiaries. A potential explanation for this result may be that parents may want to maximize the financial resources for their own family, benefitting and later

Table 2.2: Multivariate OLS Regression on WTP for Environmental Stability

	(1)	(2)	(3)	(4)
Decades condition	0.054	-0.296	-0.361	-0.296
	(0.12)	(-0.70)	(-0.86)	(-0.72)
Uncertainty	-1.454***	-1.731***	-1.668***	-1.551***
	(-3.31)	(-4.08)	(-3.96)	(-3.76)
Belief that climate changes			3.101***	1.915***
			(5.76)	(3.45)
Belief that climate change is natural			-1.041***	-1.165**
			(-3.83)	(-3.25)
Belief that technology will solve problem			-1.041***	-0.478
			(-3.84)	(-1.72)
Stated concern for short-run		1.778***		1.196*
		(3.32)		(2.28)
Stated concern for long-run		0.717		0.475
		(1.39)		(0.94)
Stated concern for very long-run		1.247***		0.919**
		(3.43)		(2.58)
Children (binary)	-1.841***			-1.056*
	(-3.55)			(-2.14)
Age	-0.067**			-0.07***
	(-3.26)			(-3.59)
Income	-0.06			-0.062
	(-0.75)			(-0.82)
Female	-0.687			-1.148**
	(-1.53)			(-2.70)
Constant	13.71***	-6.215***	4.625	-0.087
	(15.25)	(-3.72)	(1.75)	(-0.03)
N	1198	1201	1201	1198

Notes: t-statistics in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

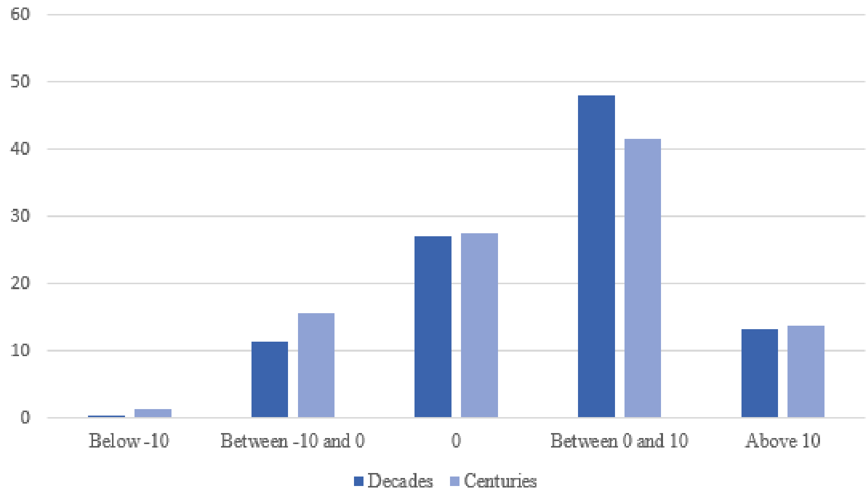
to be inherited by their children. In contrast, benefits of investments into environmental stability are distributed over many different people without the genetic link (see also Jacquet et al., 2013; Purdy, 2019). Higher income participants were not willing to give up a higher share of their income than those with lower income.

2.3.4 Beliefs and Willingness to Contribute

In the last part of our survey (after the elicitation of WTP), participants in the *uncertainty* conditions were asked how much they expect other people to be willing to give up. The belief data allow us to test whether there is a difference between people's belief about others' and their own WTP, and if so, whether people expect others to give more or less than themselves. We can also test if there is an association between their own WTP and their belief about others' WTP.

Participants in both *uncertainty* conditions on average (and at the median) believe that others are willing to give up only 4.68% of their income. Compared with an average stated own WTP of 8.3% in the *uncertainty* conditions, beliefs are thus significantly smaller than own WTP and we do not find support for our Hypothesis IV (t-Test $p < 0.001$). This implies *pluralistic ignorance* in an environmental context: people believe others to act differently compared to themselves although this is not the case (Miller and McFarland, 1987, Andre et al., 2021). There is no difference in beliefs for the *decades* and the *centuries* condition. In both treatments, more than one quarter of the participants believe that others have a WTP smaller than 1.5% of their income. Using the results concerning individual WTP and belief, we can calculate the gap between a participant's WTP and belief, defined as $WTP - Belief$. The results for this gap are shown in Figure 2.2. A negative gap implies a belief that is larger than the participant's own WTP, and vice versa for a positive gap. Only 14.5% of participants (pooled over both uncertainty treatments) state a WTP below their belief about others' WTP (i.e., free-ride). Further 27.3% indicate a WTP equal to their belief and the remaining 58.2% of

Figure 2.2: Gap between own WTP and Belief about others



Notes: A positive gap indicates a WTP that is larger than the player's belief. Figure indicates fraction of players with respective gap.

participants are willing to give up more than what they believe others would be willing to give up.

Table 2.3 replicates Table 2.2 for the *uncertainty* conditions, including individual-level belief data. We observe that the pattern of associations found in Table 2.2 remains robust after inclusion of beliefs. Moreover, a respondent's belief is strongly associated with her own WTP: a 1 percentage-point change in the WTP-belief is associated with an increase in WTP of roughly 0.85 percentage-points. We interpret this result such that the lower WTP in the *uncertainty* conditions can be explained partly by the rather pessimistic beliefs that participants have about others' WTP, assuming respondents base their own decision on their (pessimistic) beliefs (Andre et al., 2021).

Table 2.3: Multivariate OLS Regression on WTP for Environmental Stability in the Uncertainty Condition including Belief

	(1)	(2)	(3)	(4)
Belief about WTP	0.876***	0.837***	0.864***	0.814***
	(14.82)	(14.82)	(15.18)	(14.53)
Decades condition	0.307	-0.051	-0.029	-0.144
	(0.57)	(-0.10)	(-0.06)	(-0.29)
Belief that climate changes			2.642***	1.801**
			(4.12)	(2.81)
Belief that climate change is natural			-1.037*	-0.613**
			(-2.31)	(-1.38)
Belief that technology will solve problem			-1.037**	-0.489
			(-3.24)	(-1.51)
Stated concern for short-run		1.691**		1.257*
		(2.68)		(1.99)
Stated concern for long-run		0.519		0.217
		(0.89)		(0.38)
Stated concern for very long-run		1.381***		1.225**
		(3.36)		(3.01)
Children (binary)	-1.04			-0.379
	(-1.60)			(-0.64)
Age	-0.053*			-0.061**
	(-2.28)			(-2.81)
Income	0.039			0.082
	(0.40)			(0.88)
Female	-0.340			-0.732
	(-0.63)			(-1.44)
Constant	6.43***	-11.26***	-0.663	-8.824*
	(5.76)	(-5.54)	(-0.21)	(-2.33)
N	599	600	600	599

Notes: t-statistics in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

2.4 Discussion

In this paper, we present an online survey experiment with a total of 1201 participants. We find that people care about a liveable environment not only in the short-run, but also in the long-run and even the very long-run, after their own and their descendants' lifespan. Although the stated concern for the environment decreases with the respective time-scale, the overall high degree of valuation for all time-horizons shows that people value the environment to a large degree intrinsically, irrespective of any use value. This result is confirmed by our WTP elicitation, where we found a willingness to give up a substantial share of disposable income to save the environment.

On first sight, the reported WTP (more than 8% of income in all treatments) in our hypothetical measurements looks very high, especially in comparison to some incentivized studies (e.g., Diederich and Goeschl, 2014). Clearly, the nature of our inquiry with a focus on the very long-run, and comparing situations with and without a cooperation problem (to obtain non-strategic estimates of these valuations), does not lend itself to incentivized methods: There is no feasible way of credibly ensuring a stable environment in the very long run (i.e., without any potentially ambiguous policies), and any incentivized method has a public good character, with the inherent cooperation problem. Importantly, however, we asked participants whether they would be willing to give up a certain fraction of income under the assumption that the environment in general, including very different aspects (climate, pollution, biodiversity), could be kept stable, not just a certain aspect of it. That is, the current value is an all-inclusive maximum willingness to contribute, given that this will be sufficient to generally stabilize the environment, which is quite different from the measurement of WTP to, for example, retire a ton of CO2. If we consider the social cost of carbon (i.e., only one aspect of the general environment we asked for in our study), our resulting WTP lies within a very reasonable range. According to data from the World Bank, in 2018 the world-wide economy produced 0.041 tonnes of CO2 per USD 100 GDP (in 2010 USD). A social cost of carbon of USD 200 per tonne CO2 (a conservative assumption, see, e.g., Ricke et al., 2018, or Pindyck, 2019) thus implies a total damage of USD 8.2 per USD 100 in GDP, i.e., 8.2% of global GDP, which is close to the WTP values from our study. Moreover, the findings are also in line with findings of substantial willingness to contribute in recent incentivized experimental studies on more restricted impact measures (Andre et al., 2021, Fornwagner and Hauser, 2022). That is, while our study uses hypothetical scenarios, we believe it is informative on people's valuation of the environment. Clearly, an overall liveable environment can be seen as more valuable than the sum of individual aspects, lacking some dimension (e.g., biodiversity).

A key insight from our study concerns the relevance of the very long-run stability of the environment for the general population. Many environmental policies involve benefits that will not accrue to currently living generations. It is thus far from obvious whether they are "beneficial" from the perspective of current generations, who need to politically support these policies. If people did not care about the long-run, efforts to internationally coordinate climate agreements and those to protect oceans and species would potentially make little sense from the current electorate's perspective. Our data show that people do inherently care about the very long-run consequences of the current generations' economic activity. However, we find evidence for people acting like pessimistic conditional co-operators as they underestimate other's WTP while they base their own WTP-decision on this belief. Together, these findings further accentuate the importance of cooperation in intergenerational settings: Not only future generations' utility is affected through (over-)usage of the resource by preceding generations. Also, the long-term stability preferred by the current generation can only be achieved by cooperation in both current and future generations (Dengler et al., 2018). Given the tendency toward pessimistic beliefs about other people's environmental attitudes, an important problem in the intertemporal cooperation dilemma is then formed by pessimistic expectations regarding the behaviour of future generations. This emphasizes the importance of theoretical and empirical analyses of the intertemporal cooperation problem, to better understand the pitfalls in the implementation of long-run aimed policies. From a policy perspective, information, publicly visible (intertemporal) commitments, or taking a leading role as part of a successful environmental policy to positively influence people's expectations and beliefs are important. Cooperation and coordination of efforts in the presence of pessimistic views of other people's behaviour is a key aspect towards achieving the desired environmental stability.

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Appendix

2.A Experimental Instructions

General Questions

You may have heard the idea that the world's climate is changing due to increases in temperature over the past 100 years. What is your personal opinion on this? Do you think that world's climate is changing?

[Definitely changing] [Probably changing] [Probably not changing] [Definitely not changing]

Do you think that climate change is caused by natural processes, human activity, or both?

[Entirely by natural processes] [Mainly by natural processes] [About equally by natural processes and human activity] [Mainly by human activity] [Entirely by human activity] [I don't think climate change is happening]

How much do you agree with the following statement?
"New technologies to influence the climate will likely evolve in the future. Thus, there is no need to change our current life style and reduce our emission of CO2."

[Strongly agree] [Agree] [Neither agree nor disagree] [Disagree] [Strongly disagree]

Statement 1
Please indicate your degree of agreement on the following statement.
"I care about the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) in the next few years."

[Strongly agree] [Agree] [Neither agree nor disagree] [Disagree] [Strongly disagree]

Statement 2
Please indicate your degree of agreement on the following statement.
"I care about the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) in the next decades and century, even after my own lifespan."

[Strongly agree] [Agree] [Neither agree nor disagree] [Disagree] [Strongly disagree]

Statement 3
Please indicate your degree of agreement on the following statement.
"I care about the state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) in a few centuries from now, after my own lifespan, and the lifespan of all my friends, family, and their descendants."

[Strongly agree] [Agree] [Neither agree nor disagree] [Disagree] [Strongly disagree]

How much would you give up?

[Instructions for Condition long-run & no uncertainty]

Please take a minute to think about the following situation. Imagine that you give up a share of your disposable net-income to save the environment. Make the following two assumptions:

> The state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) could be kept stable in the long-run, i.e., over the next few centuries, if everyone gives up this share of their income.
>
> Everyone agreed on and committed to giving up this share.

Note that many of the benefits of giving up this share would accrue at a later time, after your own lifespan.

[Instructions for Condition short-run & no uncertainty]

Please take a minute to think about the following situation. Imagine that you give up a share of your disposable net-income to save the environment. Make the following two assumptions:

> The state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) could be kept stable only in the short-run, i.e., over the next few decades during your lifespan, if everyone gives up this share of their income.
>
> Everyone agreed on and committed to giving up this share.

Note that many of the benefits of giving up this share would accrue in the next few years.

[Instructions for Condition long-run & uncertainty]

Please take a minute to think about the following situation. Imagine that you give up a share of your disposable net-income to save the environment. Make the following two assumptions:

> The state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) could be kept stable in the long-run, i.e., over the next few centuries, if everyone gives up this share of their income.
>
> When you make your commitment to give up this share, you do not know what share of their income others will give up.

Note that many of the benefits of giving up this share would accrue at a later time, after your own lifespan.

[Instructions for Condition long-run & uncertainty]
Please take a minute to think about the following situation. Imagine that you give up a share of your disposable net-income to save the environment. Make the following two assumptions:

> The state of the environment (e.g. climate, biodiversity, air pollution, or clean oceans) could be kept stable only in the short-run, i.e., over the next few decades during your lifespan, if everyone gives up this share of their income.
>
> When you make your commitment to give up this share, you do not know what share of their income others will give up.

Note that many of the benefits of giving up this share would accrue in the next few years.

[Instructions for all conditions]
Under these assumptions, would you be willing to give up 10% of your net-income?

[Yes] [No]

[IF PARTICIPANTS INDICATED YES:] *You indicated that you would give up 10% of your income. Under the assumptions above, would you also give up 20% of your net-income?*

[IF PARTICIPANTS INDICATED NO:] *You indicated that you would not give up 10% of your income. Under the assumptions above, would you give up 5%?*

[PARTICIPANTS WENT THROUGH THE TITRATION METHOD SHOWN IN FIGURE 2.1 (SEE ABOVE). UPPER BRANCHES ALWAYS INDICATE "YES", LOWER "NO". (FIGURE NOT SHOWN TO PARTICIPANTS).]

You indicated that you would be willing to give up between [x] and [y]% of your net-income, under the assumptions above. Hence, you would give up between [$x * 10$] and [$y * 10$] EURO of each 1000 EURO of net-income you earn.

If this represents your willingness to contribute for the short-term (long-term) stability of the environment, please indicate Confirm. If you feel it does not correctly represent your willingness to contribute, please click Reconsider to change your answers.

[Confirm][Reconsider]

[IF PARTICIPANT INDICATES RECONSIDER:]
You indicated that you would be willing to give up between [x] and [y]% of your net-income, under the assumptions above. Hence, you would give up between [$x * 10$] and [$y * 10$] EURO of each 1000 EURO of net-income you earn. However, you wanted to reconsider this contribution range.
Please indicate the range of net-income you would be willing to give up to

save the environment, under the assumptions described on the previous pages.

[Participants could choose from a list with the ranges]

[If participant indicated confirm: next page was displayed]

Other people's willingness to give up [Only in the conditions with uncertainty]
How much do you think people are typically willing to give up for a stable environment in the long-run, i.e. over the next few centuries (short-run, i.e. over the next few decades), under the assumptions above? Please indicate the average share of net income that you think people are willing to give up.

[Participants could choose from a list with the ranges]

Family
On this page we would like to ask you about how many children and grandchildren you have (if any).
Number of children: [ ]
Number of grandchildren: [ ]

Thank you for taking part in our study.

2.B Further Analyses

Table 2.B.1: Distribution of WTP in the four Treatments

	Certainty		Uncertainty	
WTP	Short-run	Long-run	Short-run	Long-run
Less than 1.5	34 (11.68)	47 (15.16)	57 (20.28)	78 (24.45)
Between 1.5 and 2.5	11 (3.78)	17 (5.48)	20 (7.12)	19 (5.96)
Between 2.5 and 3.5	24 (8.25)	20 (6.45)	19 (6.76)	27 (8.46)
Between 3.5 and 5	4 (1.37)	4 (1.29)	9 (3.2)	9 (2.82)
Between 5 and 6.5	47 (16.15)	37 (11.94)	53 (18.86)	36 (11.29)
Between 6.5 and 7.5	5 (1.72)	8 (2.58)	3 (1.07)	4 (1.25)
Between 7.5 and 8.5	3 (1.03)	6 (1.94)	2 (0.71)	3 (0.94)
Between 8.5 and 10	3 (1.03)	4 (1.29)	7 (2.49)	5 (1.57)
Between 10 and 12.5	55 (18.9)	51 (16.51)	39 (13.88)	37 (11.6)
Between 12.5 and 15	22 (7.56)	27 (8.71)	7 (2.49)	30 (9.4)
Between 15 and 17.5	37 (12.71)	39 (12.58)	26 (9.25)	22 (6.9)
Between 17.5 and 20	3 (1.03)	3 (0.97)	5 (1.78)	6 (1.88)
Between 20 and 22.5	10 (3.44)	16 (5.16)	7 (2.49)	16 (5.02)
Between 22.5 and 25	7 (2.41)	3 (0.97)	7 (2.49)	5 (1.57)
Between 25 and 27.5	14 (4.81)	7 (2.26)	8 (2.85)	8 (2.51)
More than 27.5	12 (4.12)	21 (6.77)	12 (4.27)	14 (4.39)

Notes: WTP ranges in % of income. Values indicate absolute number of participants in a range. Percent share of participants in treatment in parentheses.

Table 2.B.2: Demographics and Environmental Attitudes in the four Treatments

	Certainty		Uncertainty	
	Short-run	Long-run	Short-run	Long-run
Age	34.51	33.55	36.69	36.68
	(11.21)	(11.92)	(13.17)	(13.61)
Income	5.55	5.14	5.46	5.322
	(2.90)	(2.62)	(2.66)	(2.71)
Female	0.63	0.63	0.62	0.54
	(0.48)	(0.48)	(0.49)	(0.50)
Parents	0.44	0.39	0.42	0.46
	(0.50)	(0.49)	(0.49)	(0.50)
Belief that climate changes	3.82	3.76	3.84	3.77
	(0.41)	(0.46)	(0.38)	(0.49)
Belief that climate change is natural	3.11	3.15	3.15	3.15
	(0.64)	(0.68)	(0.54)	(0.67)
Belief that technology will solve problem	1.76	1.79	1.70	1.86
	(0.89)	(0.89)	(0.82)	(0.98)
Stated concern for short-run	4.49	4.48	4.56	4.46
	(0.58)	(0.62)	(0.57)	(0.58)
Stated concern for long-run	4.42	4.36	4.48	4.40
	(0.70)	(0.69)	(0.68)	(0.71)
Stated concern for very long-run	4.20	4.14	4.21	4.12
	(0.82)	(0.89)	(0.78)	(0.91)

Notes: Values indicate mean, standard deviation in parentheses. Age in years. Income according to income ranges (0 lowest, 13 highest).

Chapter 3

Resource Control and Intertemporal Cooperation

Abstract. People's decisions influence long-term environmental stability and people care about long-term environmental stability. However, stability is not achieved in many cases due to failure of cooperation. Thus, while people care about environmental outcomes, they do not achieve sustainability because of unsustainable decisions. In this paper I argue and show that cooperation (i.e., sustainability) is negatively affected if the control over a resource switches from one group of decision makers (a "dynasty") to another, although (*i*) all individuals have an interest in the long-term stability of the resource, (*ii*) long-term cooperation is an equilibrium, and (*iii*) cooperation works if control over the resource is held by one dynasty only.

3.1 Introduction

The long-term stability of a renewable resource (e.g., a forest) or an environmental outcome (e.g., a stable climate) depends on the usage of the environmental good or the extraction of the resource by different groups and individuals. To sustain the resource, different decision makers have to cooperate with each other by not extracting too much from the resource such that the resource remains stable. In the absence of political instruments, as for example voting or punishment, individual rationality can lead to overextraction and collaps of a resource that is used by a group of individual decision makers (Hardin, 1968; Walker et al., 1990; Keser and Gardner, 1999; Casari and Plott, 2003; Ostrom, 2011; Cardenas et al., 2013; Barrett and Dannenberg, 2014; Kimbrough and Vostroknutov, 2015; Mantilla, 2018). If we consider the environmental outcome in the long-run (e.g., the goal of a 2 degree Celcius warming), contemporary cooperation is only one part of the situation, as the long-term outcome is determined by decisions made by both, groups in the present and different groups in the future. Obviously, if an earlier group behaves unsustainably, the resource loses stability already in the short-run and members of succeeding groups can consume less and receive lower utility (Chermak and Krause, 2002; Fischer et al., 2004; Jacquet et al., 2013; Hauser et al., 2014; Spiller and Bolle, 2016; Sherstyuk et al., 2016; Dengler et al., 2018; Lohse and Waichman, 2020). Only few studies take into account that the long-term survival of a resource or an environmental good matters for many individuals (Dengler et al., 2018). Be it intrinsically as people value firstly the mere existence of the resource even after one's own lifespan and secondly the wellbeing of future generations (Andreoni, 1990; Gerlagh and Michielsen, 2015), or extrinsically because people hope to gain control over the resource again, e.g., by getting reelected or by receiving a migratory resource back (Hannesson, 2013). Thus, as was shown in Chapter 2 of this dissertation, people are willing to accept additional costs or lower consumption to attain certain environmental goals. However, the effort put into sustaining a resource by one group can be undermined by a succeeding group taking over control over the resource at a later point in time (e.g., a newly elected government can withdraw from a climate policy that was agreed on by the preceding government). If the succeeding group is expected to not act sustainably, the first group may not cooperate, i.e., extract and consume more from the resource, as long-term benefits are expected to not accrue anyway, due to the behavior of the following group. I present a framework that explicitly assumes that preferences for long-term stability exist, and where long-term sustainablity requires cooperation both within a dynasty and between dynasties that use a commonly owned resource at different points in time. I argue and show that the anticipation of another group taking control over the resource leads to break down of cooperation already in the first group.

3.2 Resource Extraction Game

I use a simple infinitely repeated resource extraction game. A dynasty is a group of 3 players that can extract over multiple periods from a commonly owned resource. In each period t, each member i of the dynasty makes a decision on how much she wants to request from the resource R_t for own consumption, denoted by $y_{i,t}$ which is bounded between 0 and R_t. If $\sum_{i=1}^{3} y_{i,t} \leq R_t$ each player can extract her requested amount, denoted as $x_{i,t}$. If this inequality does not hold, i.e., requested extraction is larger than the resource, the players receive an extraction proportional to their requested amount:

$$x_{i,t} = \frac{y_{i,t}}{\sum_{l=1}^{n} y_{l,t}} * R_{j,t}.$$

At $t = 1$ the resource consists of 90 points, for $t > 1$ the size of the resource R_t is determined by the extraction in the previous period and the growth factor α as shown in equation (3.1).

$$R_{j,t+1} = \min\left(90, \alpha * \left(R_{j,t} - \sum_{i=1}^{n} x_{i,t}\right)\right) \tag{3.1}$$

R_t is bounded between 0 and 90. If $\sum_{i=1}^{n} x_{i,t} \geq R_t$, the resource is depleted and stays 0 for the rest of the game. If each player extracts the sustainable amount $x_{i,t}^{sus} = \frac{R_t}{3}\left(\frac{\alpha-1}{\alpha}\right)$ the size of the resource stays constant, i.e., $R_{t+1} = R_t$. A discount factor δ is introduced by stopping the game after each period with a probability of δ. Equation (3.2) shows the incentive condition for sustainable extraction (see Appendix for the derivation of equation (3.2)).

$$\frac{\alpha - 1}{3} \geq \frac{1-\delta}{\delta} \tag{3.2}$$

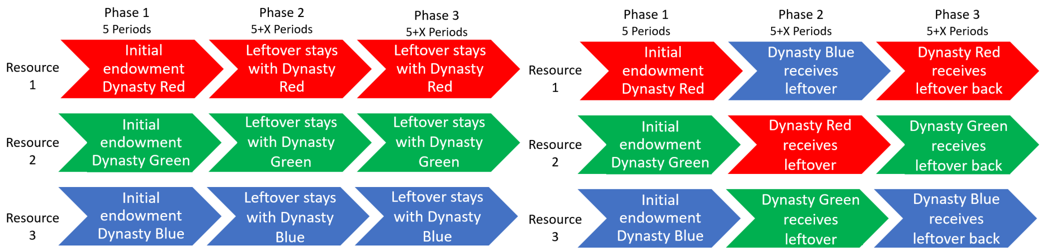
If (3.2) holds there are no incentives to extract more than the sustainable amount. If (3.2) holds with equality or if $R_t = 90$ all players extracting $x_{i,t}^{sus}$ is the socially optimal equilibrium (out of many other equilibria).

In the experimental implementation I use a growth factor of $\alpha = 1.5$ which leads to $x_{i,1}^{sus} = 10$. With the fixed $\delta = 0.9$, inequality (3.2) holds and the cooperative equilibrium exists. This equilibrium contains no punishment for deviation, so all strategies that include such reactions (e.g., Grim-Trigger) can be played in equilibrium as well. Full exhaustion of the resource in $t = 1$ is also an equilibrium, although leading to lower expected individual payoff. In the experiment players are informed about the extraction decision of each member of their group in the previous period, and about the sustainable extraction for their group in the current period before deciding on how much to extract.

The experiment consits of two parts. The first part lets participants get acquainted with the structure of the game and the outcomes of group actions, and the second part implements the game for two conditions (between-subject design). In the first part, the resource extraction game is played three times where each single game is independent of the others. Each game is played for at least five periods, after each succeeding period the game ends with a probability of 10%.

The second part of the experiment consists of three *connected* phases. A dynasty is endowed with 90 Points in period 1 of phase 1, and the size of the resource in the beginning of phases 2 and 3 is determined by the extraction in the previous phase. Phase 1 is played for exactly five periods, phases 2 and 3 last at least five periods followed by the same stopping mechanism as in

Figure 3.2.1: Resource in the two Conditions



(a) Maintained Control (b) Switched Control

Notes: This is an example with three dynasties (Red, Green, and Blue). The same scheme applies for any other number.

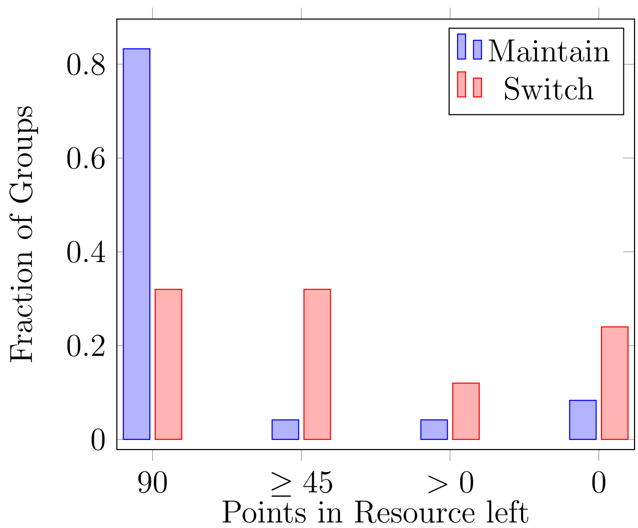
part 1 ($\delta = 0.9$). There is no interaction between dynasties in the *Maintained Control* (*maintain*) condition, where control over a resource remains with one dynasty over all three phases (see Figure 3.2.1a). In contrast, the *Switched Control* (*switch*) condition introduces an intertemporal linkage between two dynasties as control over the resource switches from one dynasty to another and back again. Here, the resource is used by one dynasty in phase 1, handed over to another dynasty in phase 2, and is then given back to the first dynasty in phase 3 (see Figure 3.2.1b). Because of phase 3, the initial dynasty has an incentive to keep the resource stable in the long run. Thus, the long-term preferences that we found in the study presented in Chapter 2 and that can be observed in everyday life are induced in the lab. Note that a setting in the lab is used, such that no two dynasties directly swap resources. This is to prevent situations where one dynasty may directly "retaliate" for receiving a lower phase 2 endowment then they themselves left, or the anticipation of such retaliation. Instructions, screenshots, and further details about payments and experimental procedures can be found in the methods section and in this chapter's Appendix.

The main focus of the analysis lies on the differences between the two conditions in phase 1 of part 2: I want to test whether the anticipation of another dynasty temporally taking over the resource leads to a failure of cooperation. In both conditions there are no incentives to deviate from sustainable extraction in phase 1. Phase 3 is the same for both conditions and consists only of the infinitely repeated resource extraction game where sustainable extraction is an equilibrium. This is an equilibrium in the infinitely repeated game of phase 2 as well (no matter which dynasty plays this phase), so extracting $x_{i,t}^{sus}$ in phase 1 of part 2 is therefore an equilibrium in both conditions: In the maintain condition, sustainable extraction leads in expectation to an individual total extraction of 50 Points in phase 1 and 150 Points in phases 2 and 3 since the stopping mechanism leads in expectation to 10 additional periods. If an individual deviates in the last round of phase 1 and indicates an extraction of the full 90 Points and the other two players request the sustainable amount of 10 Points, she receives 73.64 Points in that period. So compared to extracting sustainably, she gains 63.64 Points but loses in expectation 300 Points from phases 2 and 3. The same argumentation holds for the switch condition, even if we assume the best case for the defector in which defection in phase 1 is not punished by other group members in phase 2. Then she receives the 73.64 Points in the end of phase 1, her group takes over a leftover of 90 Points in phase 2, and all members of her group (including herself) extract sustainably in phase 2. The additional 63.64 Points are much smaller than the (expected) loss of 150 Points in phase 3 due to her deviation in phase 1. Possibly, she also loses a large part of the 150 Points from phase 2 as her peers might punish her earlier defection. Hence, we can formulate a hypothesis that can be tested in this design:

> *Hypothesis: Players in both conditions extract sustainably and there is no difference in leftover after phase 1 in the two conditions.*

The design of the switch condition models a best case compared to the typical situation outside the lab. Firstly, members of a dynasty know for sure that they will use the resource in the future again. This induces long-term preferences and covers all situations where those preferences exist, be it due to the intrinsic valuation of the long-term stability of a resource or because the dynasty receives back control over the resource. Secondly, the second dynasty has no incentives to deviate from playing sustainably. Cooperation within and between dynasties is feasable and a failure of cooperation (rejection of the hypothesis), i.e., depletion of the resource in an early stage, can be interpreted as a distrust by the first dynasty in the willingness or ability to cooperate of the second dynasty, or the expectation of a player that other members of her own dynasty extract unsustainably due to a pessimistic belief about the behavior of the following dynasty. If we observe such a failure even in this (best) case, we expect cooperation to fail in many real world situations as well, as mostly one or both conditions for the best case are not fully met (e.g., some members of a generation have no long-term preferences to sustain a stable climate as they might have no intrinsic valuation, or they know for sure that they will not enjoy the advantages of a stable climate in some distant future themself).

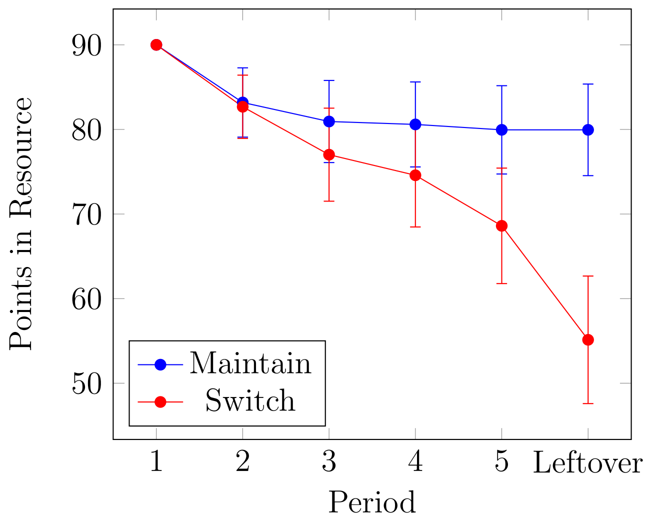
Figure 3.2.2: Leftover after Phase 1



3.3 Results

A failure of cooperation will lead to exploitation of the resource in an early stage, i.e., before the beginning of phase 2 in the experiment. At first we can observe that dynasties in the maintain condition manage to cooperate: more than 80% of groups in the maintain condition left the entire resource at the end of phase 1, whereas only 8.3% left nothing (see Figure 3.2.2). With the intertemporal linkage between two dynasties this picture strongly changes;

Figure 3.3.1: Development of R_t in phase 1 and leftover



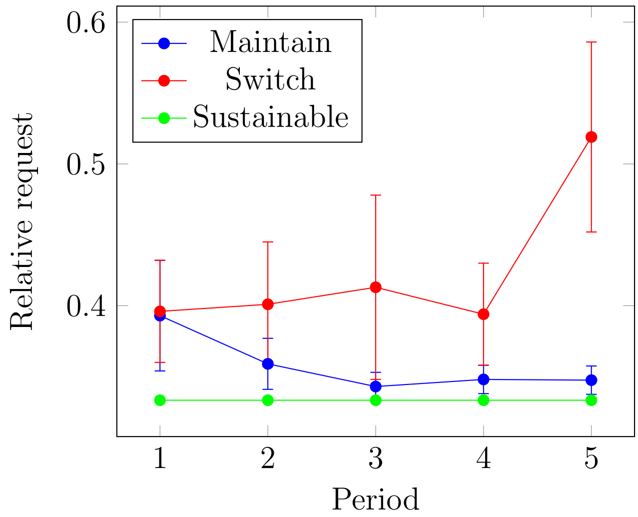
Notes: Whiskers indicate Standard Errors

only 32% of groups in the switch condition left the entire resource and 24% exhausted the resource during the first phase. On average, groups in the maintain condition left 79 Points and groups in the switch condition left 55 Points, so I reject the hypothesis (Mann-Whitney-U Test p=0.001).

A similar picture emerges if we take a look at the development of R_t in the two conditions. Figure 3.3.1 shows the mean size of the resource in both conditions for the first phase and the first period of phase 2 (to capture the leftover). The graph shows that R_t is decreasing fast in the switch condition whereas R_t is stable in the maintain condition. The difference between conditions is significant for the leftover after the fifth round, when cooperation strongly breaks down. That means that many players increased their extraction in the fifth round, and some players anticipated that increase in an earlier period.

The relative request of a group is defined as the sum of individual extraction decisions in t divided by R_t (this can be different to the amount that was realy extracted, because the sum may be greater than the resource itself). It exceeds on average the sustainable amount in both conditions (see Figure 3.3.2). The difference between the two conditions is only significant for the

Figure 3.3.2: Mean Relative Request in Phase 1



Notes: Whiskers indicate Standard Errors

fifth period (Mann-Whitney-U Test $p < 0.01$). There is greater variance in extraction in the switch condition (Variance-Ratio Test $p < 0.001$), where there are some individuals who cooperate and extract (close to) the sustainable amount, and others whose extraction is twice as high as $x_{i,t}^{sus}$. While in both conditions groups extract on average 40% of the resource in the first period (1/3 would be sustainable), extraction *decreases* in the maintain condition to 35% in the fifth round and *increases* in the switch condition to over 50% of the resource.

The results suggest that participants in the switch condition distrust their succeeding dynasty, or expect others from their own dynasty to do so, and, hence, extract more than the sustainable amount at the end of phase 1. However, if we take a look at the maintain condition, we see no evidence for failure of cooperation in the second phase. In total 75% of groups in the maintain condition left the entire 90 Points at the end of phase 2 and 90% of those groups that left 90 Points after phase 1 also ended phase 2 with 90 Points. This means that the theoretically shown sustainable equilibrium is practically feasable and played by most of the groups. Hence, there is no obvious reason for the first dynasty to believe that their resource will be exhausted during the second phase if they leave the resource intact after phase 1.

3.4 Conclusion

In this paper I presented a framework that explicitily includes long-term preferences and shows that a (temporary) change of control over a resource leads to exploitation of the resource at an early stage. However, long-term stability is achieved when control over the resource remains with one dynasty.

The results suggest that policies or agreements that are not binding for both, current *and* future groups of decision makers, or that future governments can easily withdraw from (as it was the case with the Paris Agreement) are less successfull in reaching long-term sustainability. Even if all current and future decision makers want to achieve environmental stability, changing control over the environmental good undermines cooperation. Hence, although people care about environmental outcomes and are willing to make costly decisions to reach those goals, policies and international agreements should take future actions into account. They should include some intertemporal "commitment devices", such as irreversible investments, to make the policy more efficient and to foster cooperative, sustainable behavior in the present and the future.

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Appendix

3.A Methods

The experiment was programmed in oTree (Chen et al., 2016) and was conducted between December 2019 and February 2020 in the AWI lab, the laboratory for economic experimets of the Heidelberg University. In total there were 147 participants leading to 24 groups in the maintained control condition and 25 groups in the switched control condition which is sufficient according to the power analysis. Participants were mostly students from Heidelberg University and in each session there were either 12, 15, or 18 participants.

At the end of the experiment one period from part one (training) and one from part two (main experiment) was chosen randomly and participants received whatever they earned in the chosen period with an exchange rate of 1 Point = €0.5 in part one and 1 Point = €1 for part two and an additional show-up fee of €3. Participants earned on average €12.66. The groups in each session were assigned to one condition (maintain or switch) so the analysis is between subject.

3.B Derivation of Equation (3.2)

To get to inequality (3.2) for the general case with n players, first define the strategy Always Cooperate (AC) as $x_{i,t} = x_{i,t}^{sus}$ $\forall t$ and the strategy Deviate Once (DO) as $x_{i,T} = x_{i,T}^{sus} + \epsilon$ if $t = T$ and $x_{i,t} = x_{i,t}^{sus}$ else, with $\epsilon \leq R_T - n x_{i,t}^{sus}$. Define $U_i(.)$ as the discounted sum of current and future extraction.

We can write

$$U_i(AC) = \sum_{t=0}^{\infty} \frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right)\delta^t.$$

Hence,

$$U_i(AC) = \frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right)\frac{\delta}{1-\delta} + \frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right).$$

Accordingly, form

$$U(DO) = \frac{R-\epsilon\alpha}{n}\left(\frac{\alpha-1}{\alpha}\right)\frac{\delta}{1-\delta} + \epsilon + \frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right).$$

To see whether there is an incentive to deviate once from the sustainable extraction and take some ϵ more, we first define

$$b = \left(\frac{\alpha-1}{\alpha}\right)\frac{\delta}{1-\delta}.$$

Then, we can rewrite $U_i(AC) \geq U_i(DO)$ as

$$\begin{aligned}
&\frac{R}{n}b \geq \frac{(R-\epsilon\alpha)}{n}b + \epsilon \\
&\Leftrightarrow Rb \geq \epsilon n + Rb - \epsilon\alpha b \\
&\Leftrightarrow \alpha b \geq n
\end{aligned}$$

Remember the definition of b and insert $n = 3$ to receive the condition under which there are no incentives to take (once) more than sustainable

$$\frac{\alpha-1}{3} \geq \frac{1-\delta}{\delta}.$$

If a player indicates to extract the entire R_t, she will receive

$$U_i(R) = \frac{R^2}{R + (n-1)\frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right)}.$$

If the following inequality is fulfilled, there is no incentive to try to extract the entire resource

$$\frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right)\frac{\delta}{1-\delta}+\frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right)\geq\frac{R^2}{R+(n-1)\frac{R}{n}\left(\frac{\alpha-1}{\alpha}\right)}$$
$$\Leftrightarrow\frac{\alpha-1}{n\alpha(1-\delta)}\geq\frac{n\alpha}{n\alpha+(n-1(\alpha-1)}$$

With the parameters used here, both conditions are fulfilled. As with the discount factor $\delta = 0.9$ there are in expectation 10 more periods to come it is not profitable to extract the entire $R = 90$ even if the other two players extract 0 Points.

3.C Sample Size

In order to analyse how large the sample has to be to find an effect (if an effect exists), I constructed an artificial data set. Each observation in this set corresponds to the resource that a group carried over from phase 1 to phase 2. In the extreme case a group will either cooperate and carry over the entire 90 Points, or fail to cooperate and carry over 0 Points. Table 3.C.1 summarizes the results of a Mann-Whitney-U Test for the respective effect and sample size, where a is the fraction of groups that cooperate, i.e., the effect size is displayed in the third column.

Table 3.C.1: Sample Size

a in maintain	a in switch	Difference in a	Groups per condition	p-value
2/3	1/3	1/3	6	0.269
2/3	1/3	1/3	9	0.1693
2/3	1/3	1/3	12	0.1099
2/3	1/3	1/3	15	0.0726
2/3	1/3	1/3	18	0.0486
0.8	0.5	0.3	20	0.0495
0.75	0.5	0.25	20	0.1069
0.7	0.5	0.2	20	0.2024

If we put up the constraint that the effect has to be larger than 0.25 to be of interest (e.g., in one treatment 75% of the groups carry over 90 Points whereas in the other treatment only 50% of the groups do so), we see that the analysis with 20 observations per treatment will find the effect.

3.D Experimental Instructions

The whole experiment was conducted in German (the German version of the instructions is availabe on request). Before part one began participants received the instructions for part one only so there were no differences between the conditions during the first part. Instructions for the entire second part were displayed before the first phase of part two.[1] A short summary of the following phase was displayed before the respective phase. This summary included the most important information and did not include any new information. Part two was followed by a short demographic questionaire.

Instructions Part 1

Welcome to todays experiment.

Please do not talk to another anymore and turn off your mobile phone. Read the following instructions carefully. Raise your hand if you have a question. All other participants receive the same instructions.
The experiment consists of two parts. You find the instructions for the first part below. You can earn money in both parts of the experiment. Your total payoff is the sum of your earnings from parts 1 and 2 and an additional fixed amount of €3.

In the first part you will play a game that consists of at least 5 rounds. After the fifth and each succeeding round a next round will take place with a probability of 0.9 and with a probability of 0.1 the game ends. The game will be played in total three times. After the last round of the third game part 1 of the experiment will end.

[1]These included the respective figure you can find in the main text of this work

You will be devided into groups of three at the beginning of the experiment. These groups will not change during the entire experiment. Hence, you will play in both parts and in all rounds of the experiment with the same two other participants.

Your group receives in the first round of the game a commonly used resource consisting of 90 Points. In each period you must decide how many Points you want to extract from the resource for yourself. The other members of your group face the same decision. After each round all members of your group will be informed about how much each member extracted.

At the end of each round the remaining resource will grow by 50% but can not grow larger that 90. The new amount will be your endowment in the next round and you and the other members of your group can again decide on how much to extract from the resource. Important: In each period you will be informed about the sustainable extraction of your group, that means how much your group can extract such that the resource will have the same size in the next round as it had in the preceeding.
If the sum of indicated extraction in your group is smaller or equal to the current size of the resource in one round each member of the group will receive her indicated extraction. If this sum is larger than the resource, each member will receive a fraction of the resource that is proprtional to her indicated extaction. If the resource is entirely exhausted it will have a size of 0 Points in the following rounds and you can extract only 0 Points anymore. However, at the beginning of each of the three games the group will start with a resource containing 90 Points.

At the end of part 1 one of the games you played is chosen randomly. One round of this repitions is chosen randomly and you will receive a payoff according to the amount you extracted in this round. You receive €0.5 for each Point you extracted.

Instructions Part 2: Maintain Condition

The second part of the experiment consists of 3 connected phases that again consist of multiple rounds. You find the instructions for all three phases below. At the beginning of each new phase you will again receive the instructions for the respective phase.
The groups will be the same as in part 1. Hence, you will play in all three phases and all rounds of part 2 with the same two participants as in part 1.

The first phase will be played in principle according to the same rules as in the first part of the experiment. However, different to the previous games, the first phase is played for **five rounds for sure**. In the first round your group is endowed with a resource with a size of 90 Points. After 5 rounds phase 1 ends and the second phase begins.

In phase 2 you will play the same game again. However, your group's endowment in the first round of phase 2 will be the leftover of the resource after the fifth round of phase 1. Phase 2 is played for at least five rounds. However, as in part 1, after the fifth and each succeeding round a next round will be played with a probability of 0.9. If no next round takes place phase 2 ends and phase 3 begins.

The same rules apply as well for phase 3. The endowment in phase 3 equals the leftover of your resource after phase 2. Phase 3 is played for at least five rounds. Afer the fifth and each succeeding round a next round will be played with a probability of 0.9. After the last round of phase 3 the experiment ends.

At the end of the experiment one round is chosen randomly from one randomly chosen phase. You receive the Points you extracted in that round, now with an exchange factor of one Point = €1.

Hence, the differences to part 1 are the following: (1) the endwoments in phases 2 and 3 will equal the leftover of the previous phase, (2) phase 1 lasts exactly five rounds, and (3) 1 Point translates to €1.

Instructions Part 2: Switch Condition

The second part of the experiment consists of 3 connected phases that again consist of multiple rounds. You find the instructions for all three phases below. At the beginning of each new phase you will again receive the instructions for the respective phase.
The groups will be the same as in part 1. Hence, you will play in all three phases and all rounds of part 2 with the same two participants as in part 1.

The first phase will be played in principle according to the same rules as in the first part of the experiment. However, different to the previous games, the first phase is played for **five rounds for sure**. In the first round your group is again endowed with a resource with a size of 90 Points. After 5 rounds phase 1 ends and the second phase begins.

After the fifth round of phase 1 some part of your group's resource will be left (this part might also be 0). **This leftover of part 1 will be the endowment of some other group in phase 2. At the same time your group will receive the leftover of some other group as the endowment for phase 2** (but this is not the group that receives your group's resource).

In phase 2 you will again play the same game as before; but the endowment of your group in the first round of phase 2 equals the leftover of some other group after the fifth round of phase 1. Phase 2 lasts for at least five rounds. As in part 1, after the fifth and each succeeding round a next round takes place with a probability of 0.9. If no next round takes place, phase 2 ends and phase 3 begins.

After the last round of phase 2 some part of the resource will be left (this part might also be 0). In Phase 3 this leftover of your group will be the endowment of the group who's resource your group received at the beginning of phase 2. At the same time your group receives the leftover of the group that received your group's resource at the beginning of phase 2 as the endowment of phase 3.

In phase 3 the same rules apply as in phase 2. The endowment in phase 3 equals the *leftover* of the other group at the end of phase 2. Phase 3 lasts for at least five rounds. After the fifth and each succeeding round a next round takes place with a probability of 0.9. If no next round takes place, phase 3 and hence the experiment will end.

At the end of the experiment one round is chosen randomly from one randomly chosen phase. You receive the Points you extracted in that round, now with an exchange factor of one Point = €1.

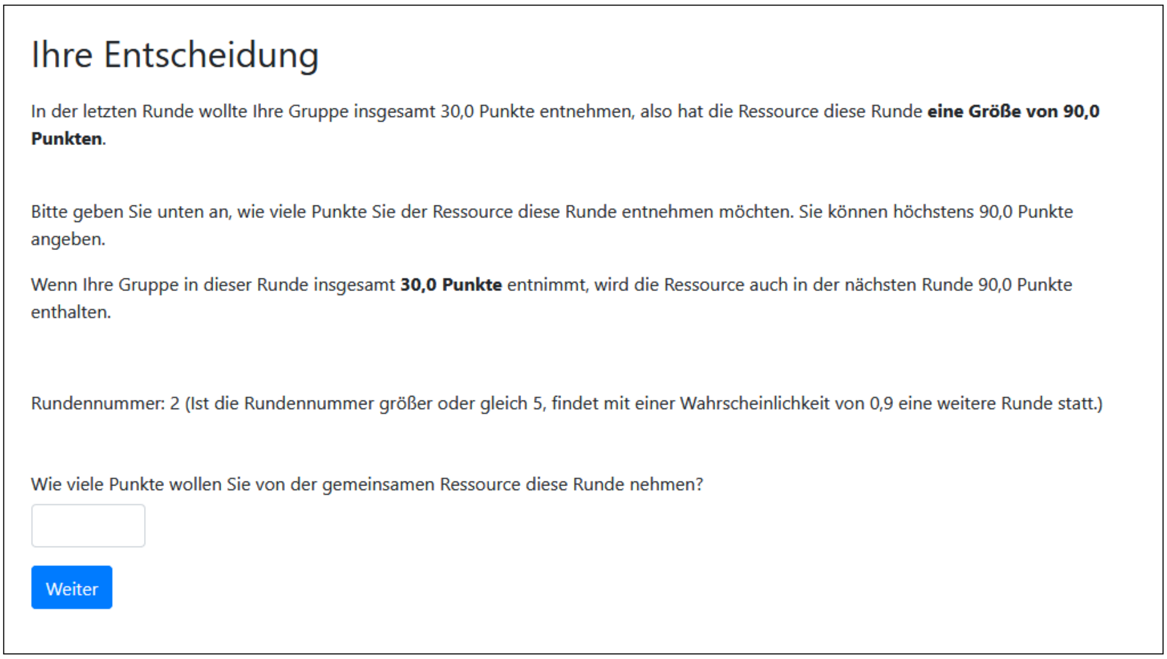
Hence, the differences to part 1 are the following: (1) the endwoments in phases 2 and 3 depend on the behavior of your and some other group in the previous phase, (2) phase 1 lasts exactly five rounds, and (3) 1 Point translates to €1.

Summary

During the experiment your group's resource will be used within the three phases by your group, then by some other group, and then again by your group. If the resource is exhausted at the end of phase 1 the group that receives your leftover in phase 2 can not extract any Points and you can not extract any Points in phase 3. If at the end of phase 1 some Points are left and the group that receives those Points in phase 2 uses them up, you can not extract any Points in phase 3. The same holds for the resource that you will receive from some other group in phase 2.

3.E Screenshots

Screenshot Decision



Ihre Entscheidung

In der letzten Runde wollte Ihre Gruppe insgesamt 30,0 Punkte entnehmen, also hat die Ressource diese Runde **eine Größe von 90,0 Punkten**.

Bitte geben Sie unten an, wie viele Punkte Sie der Ressource diese Runde entnehmen möchten. Sie können höchstens 90,0 Punkte angeben.

Wenn Ihre Gruppe in dieser Runde insgesamt **30,0 Punkte** entnimmt, wird die Ressource auch in der nächsten Runde 90,0 Punkte enthalten.

Rundennummer: 2 (Ist die Rundennummer größer oder gleich 5, findet mit einer Wahrscheinlichkeit von 0,9 eine weitere Runde statt.)

Wie viele Punkte wollen Sie von der gemeinsamen Ressource diese Runde nehmen?

Weiter

Your decision

Your group wanted to extract 30.0 Points in the previous period, so the resource has **a size of 90.0 Points** in the current period.

Please indicate how many Points you want to extract from the resource in the current period. You can not state more than 90.0 Points.
If your group extracts in total **30.0 Points** the resource will include 90.0 Points in the next period as well.

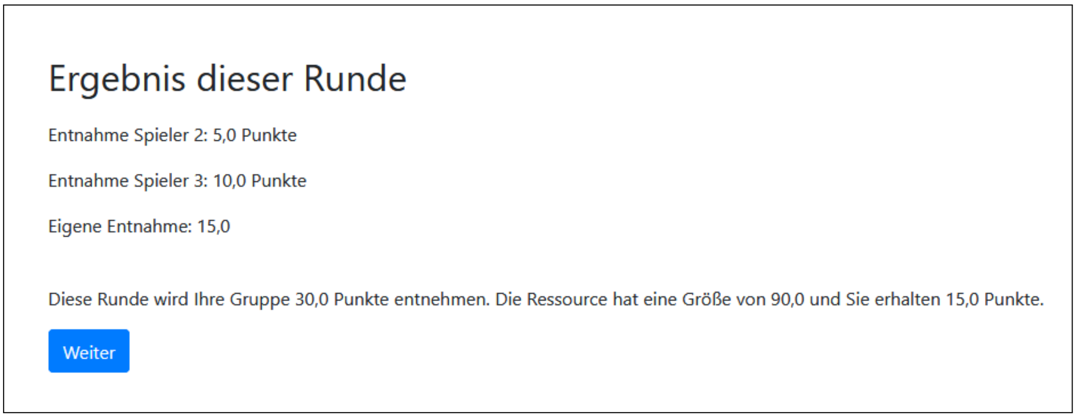
Roundnumber: 2 (If the roundnumber is larger or equal 5, with a probability of 0.9 a next round will take place.)

How many Points do you want to extract from the common resource in this period?

[ ]

[Continue button]

Screenshot Results



Results of the current period

Extraction player 2: 5.0 Points
Extraction player 3: 10.0 Points
Own extraction: 15.0

Your group will extract 30.0 Points in the current period. The resource has a size of 90.0 Points and you earn 15.0 Points.
[Continue button]

Chapter 4

Within-group Cooperation and Between-group Spillover

Abstract. Decisions we make today determine the state of the environment and the benefits we can draw from the environment in the future. If potential benefits are large enough they can make cooperation (i.e., sustainable behavior) an equilibrium within a group of decision makers. However, in many cases the long-term benefits depend not only on decisions made in a local group, but also on those made in other groups as there is a spillover between different groups. In this paper, I design a model that shows that in such situations there exist tipping dynamics: if because of other groups' unsustainable actions the long-term benefits become too small, the sustainable within-group equilibrium breaks down. This result is supported by an experiment where cooperation rates within a group significanlty decrease as soon as this point, that I will define as the "political tipping point", has been reached.

4.1 Introduction

The long-term outcome of many environmental goods is determined by today's decisions on how to use those goods. To achieve environmental stability in a certain domain, e.g., a stable climate, or no substantial loss in biodiversity, multiple decision makers have to cooperate with each other and use the respective environmental good sustainably. Those decision makers can be, for example, political parties, countries' representatives, or individual consumers. However, while they act within a certain group of decision makers, the consequences of (non-) cooperation are often shared across multiple groups of decision makers. Hence, to achieve the common environmental aims, cooperation is necessary not only within a group but also between those connected groups.

To make the argument clearer consider the example of a tropical rain forest spreading over multiple countries. Individuals in those countries want to harvest timber to make (short-term) profits. Overextraction of this resource, i.e., large scale deforestation, will lead in the long-run to a decline in ecosystem services provided by the forest (e.g., biodiversity (Curran et al., 2004), or precipitation (Smith et al., 2023)). However, the ecosystem services depend on the state of the entire forest spreading over multiple countries. Hence, while short-term profits are realized by individual decision makers within a country, the decline in long-term benefits (in this case the ecosystem services) affects decision makers in other countries as well. This implies that sustainable behavior in a single country is not sufficient to stabilize ecosystem services as the long-term outcome depends on extraction decisions made in *all* countries sharing the forest. Hence, there is a spillover between groups in the effect on long-term benefits of within-group actions.

In such situations where long-term benefits from cooperation exist, i.e., where people hold long-term preferences for the environment (as was shown in Chapter 2), and those long-term benefits will be shared and are affected by different groups, one group's actions impact incentives in other groups. Incentives to cooperate depend on the state of the environmental good and the state of the environmental good is determined by decisions on how to use this good. If other groups act sustainably, cooperation in a decision maker's own group leads to the preferred environmental outcome and there are substantial incentives to individually cooperate and cooperation can be a within-group equilibrium. However, if other groups act unsustainably the long-term benefits cannot be reached irrespective of cooperation within an individual's own group. Hence, there are lower incentives for her to cooperate and the benefits from defection (i.e., using the environmental good unsustainably) outweigh benefits from cooperation. This implies that, if cooperation in other groups falls below a certain threshold (or is expected to do so), the cooperative within-group equilibrium will break down. I will call this threshold the *political tipping point*: if this point is reached the cooperative equilibrium breaks down due to the spillover from other groups' actions on incentives in one's own group. In this paper I present a novel framework that models a social ecological system where the state of the environment determines within group equilibria and group behavior determines the state of the environment with spillovers between groups that allows me to locate and analyse the political tipping point.

The rationale behind the present study is closely related to experiments on multi-level public goods. These studies assume that there are different levels on which cooperation can take place, a global and a local one, where the small (local) group is nested in a larger (global) group (Wit and Kerr, 2002). In those studies players can decide on whether they want to invest in a "local" or a "global" public good, where the "local" good provides benefits on a smaller number of people than investments in the "global" public good (Buchan et al., 2009, Fellner and Lünser, 2014, Chakravarty and Fonseca, 2017, Gallier et al., 2019, Catola et al., 2023, Gross et al., 2023). These studies suggest that there is a trade-off between how much to invest locally versus globally, where global cooperation (i.e., investments in the "global" public good) is more efficient, but more difficult. However, in many real-world situations one decision affects both levels, the local and the global level, e.g., deforestation or air pollution that both have local and global effects (Wang et al., 2011, Güth and Sääksvuori, 2012). Hence, in many situations the real trade-off is not between investing either locally *or* globally, but rather between individual profits and externalities imposed on one's own and other groups as there is a spillover of detriments from non-cooperation within a group on other groups. As argued above such spillovers can imply tipping dynamics as they make other groups' actions a determinant for the set of within-group equilibria.

The framework fulfills the criteria for tipping points defined by Milkoreit et al. (2018): a marginal change in the state of the environment caused by non-cooperation of other groups changes within group incentives abruptly, leading to a break-down of the cooperative equilibrium. This induces less cooperation within the affected group and, hence, a negative feedback loop evolves that makes returning to a sustainable path nearly impossible.

Tipping dynamics play a crucial role in many social ecological systems. Some recent papers investigate tipping dynamics in social systems where small changes in the social system can have large impacts on a higher level. Otto et al. (2020) find various potential social tipping elements that can enhance climate actions, e.g., in the education system or in financial markets. They think of social tipping elements as subsystems of society that interact with the ecological system such that a small change in this subsystem can have large effects on the whole social system. In triggering such tipping elements norms play a crucial role (Nyborg et al., 2016, Welsch, 2022). If it is perceived as the social norm to act environmentally friendly, people will be more likely to engage in environmentally friendly activities as well. Hence, if a critical mass acts sustainably (or is perceived to do so) other decision makers will react and change their behavior as well to act in line with the norm.

Some experimental research included tipping points in the ecological system to study cooperation in groups (e.g., Milinski et al., 2008, Tavoni et al., 2011, and Barrett and Dannenberg, 2014). In those experiments, participants played a threshold public goods game with an externally defined risk of catastrophe if total investment stays below the threshold. Cooperation has been found to be affected by the threat of reaching a tipping point and cooperation rates increase with a higher risk of catastrophe but stay overall on a low level.

While the previously mentioned studies focused on tipping points either in the ecological or in the social system, I argue that a marginal change in the structure of the ecological system can have substantial effects on the social dynamics which will in turn have large impacts on ecology. In the present paper, I will study tipping points that emerge through this interplay between the social and the ecological systems. In my framework the current state of the global environmental good determines the set of equilibria within local groups and equilibrium choice determines the state of the environmental good. That is, the social and the natural system are interconnected and depend on each other while previous research often focused on one of the two, despite the high relevance of the interconnectedness (Reid et al., 2010, Folke et al., 2011, Donges et al., 2018, Censkowsky and Otto, 2021).

In the next section I will present the theoretical framework that models a social ecological system in the context of a common pool resource with spillovers of within group behavior on other groups' incentives for cooperation. The third section presents the experimental design that implements the game in a lab experiment. The results of this experiment are presented in the fourth section before the last section concludes.

4.2 Model

4.2.1 Structure and Payoff

The model is based on a multi-period common pool resource game with a renewable resource, comparable to the game presented in Chapter 3, but with a finite number of rounds. There are m groups with n players per group. Each group j is endowed in the first of T periods with a resource endowment of size E. In each period t, player i can request her individual consumption $y_{i,t}$ from the group's current resource in the respective period, denoted as $R_{j,t}$. $y_{i,t}$ must not be smaller than 0 or larger than $R_{j,t}$ and $R_{j,t}$ is bounded between 0 and E. If $\sum_{i=1}^{n} y_{i,t} \leq R_{j,t}$, each player can extract her requested consumption. Realized extractions are denoted as $x_{i,t}$, so in this case, $x_{i,t} = y_{i,t}$. If the above inequality does not hold and the sum of requests is larger than the group's resource, the players will realize an extraction proportional to the requested consumption:

$$x_{i,t} = \frac{y_{i,t}}{\sum_{l=1}^{n} y_{l,t}} * R_{j,t}.$$

After each period, the remaining resource grows by the growth-factor $\alpha > 1$ but cannot grow larger than the initial endowment. The size of the resource in each period is determined according to equation (4.1) (which is just the same as in Chapter 3). If the sum of individual requests is larger than the resource itself, it is depleted and stays 0 for the rest of the game.

$$R_{j,t+1} = \min\left(E, \alpha * \left(R_{j,t} - \sum_{i=1}^{n} x_{i,t}\right)\right) \tag{4.1}$$

Because of the renewable character of the resource, sustainable extraction is possible. If each member of the group extracts the sustainable amount $x_t^{sus} = \frac{R_{j,t}}{n}\left(\frac{\alpha-1}{\alpha}\right)$, the size of the resource stays constant and $R_{j,t+1} = R_{j,t}$.

Player i's total payoff π_i consists of two parts: $\pi_i = \pi_{1,i} + \pi_{2,i}$. The first part ($\pi_{1,i}$) represents the individual's short-term profits from resource extraction and equals the average realized extraction in the T periods (i.e., a simple recalibration of accumulated extraction; see equation (4.2)).

$$\pi_{1,i} = \frac{1}{T}\sum_{t=1}^{T} x_{i,t} \tag{4.2}$$

The second part of group j's members' payoff, $\pi_{2,i}$, implements the two key assumptions of the model. First, I assume that people value the long-run outcome of the resource intrinsically and receive additional utility from a stable environment. A better environmental outcome is associated with a higher utility and, hence, the realized long-term benefit depends on how much the group leaves in their resource after the T periods. This leftover of group j is formed equivalently to equation (4.1), i.e., the remainder after period T is multiplied with the growth-factor α to form a group's leftover L_j. An individual's valuation of a perfectly intact resource is given by b which is her maximum possible long-term benefit. $\pi_{2,i}$ decreases with a lower leftover:[1]

$$\pi_{2,i} = b * \frac{L_j}{E} \tag{4.3}$$

Second, there is a spillover between different groups of decision makers. An individual's long-term benefit depends on the long-term outcome of the environmental resource and this long-term outcome is determined not only by the group's own actions but also by other groups' behavior. Hence, the utility decreases not only with a lower own group's leftover but also with lower other groups' leftover and $\pi_{2,i}$ is formed as shown in equation (4.4).

$$\pi_{2,i} = b * \frac{L_j}{E} * \left(\frac{\sum_{h=1,h\neq j}^{m} L_h}{(m-1)E} \right)^p \tag{4.4}$$

As in equation (4.3) $\pi_{2,i}$ is bounded between 0 and b. The parameter p in equation (4.4) indicates the magnitude of spillover between groups, i.e., how strong a group's long-term benefit depends on actions taken in other groups (p can only take non-negative values). If other groups perfectly cooperate, a long-term payoff of b is possible. However, if other groups fail to cooperate and deplete their resource (and $p \neq 0$), long-term benefits will be 0, independent of cooperation in the respective own group. In the remainder of this paper I will define k_j as an indicator for cooperation in other groups than group j:

$$k_j = \frac{1}{(m-1)} \sum_{h=1,h\neq j}^{m} \frac{L_h}{E}. \tag{4.5}$$

If p is close to or equal to 0, the other groups have (nearly) no effect on a group's long-term benefit, e.g., a local forest that is not affected by actions taken in other areas.[2] Accordingly, a large p refers to high dependence on other groups, e.g., in the case of global climate change where a country's long-term outcome strongly depends on actions taken in other countries.

[1] The main results do not change with a more general functional relationship.

[2] I will stick to the convention of defining $0^0 = 1$ (Knuth, 1992)

4.2.2 Equilibria and Political Tipping Point

For the analysis of the above model and the political tipping point I define three different cases: *i.)* $k_j = 0$, *ii.)* $k_j = 1$, and *iii.)* $0 < k_j < 1$. The first two cases represent the two extreme cases where the other groups either deplete their entire resource or perfectly cooperate and keep the resource stable. For the analysis of players' extraction decisions I will focus on cases with $R_{j,T} \neq 0$ since in all other cases players can not choose between different strategies and can only request 0 units from the resource. In this section I further only consider cases with $p \neq 0$.

Case i.) $k_j = 0$
In this case $\pi_{2,i} = 0$ and player i's overall payoff consists only of her extraction and is formed according to equation (4.2). As the number of periods T is fixed and common knowledge, it is individually optimal for all members of group j to request $y_{i,T} = R_{j,T}$ which implies $x_{i,T} = R_{j,T}/n$. Hence, there is no cooperative equilibrium in the last period and, depending on the exact parameters, it can be the unique equilibrium that all members of group j request $R_{j,1}$ in period 1 and the resource stays at 0 for the rest of the game.

Case ii.) $k_j = 1$
In the second case the last term of equation (4.4) equals 1 and can be reduced to equation (4.3). If player i extracts some amount $x_{i,T}$ in the last period, which can but need not equal the sustainable amount, her group will have a leftover of L_j. If she decides to extract some amount ϵ more (i.e., $x^*_{i,T} = x_{i,T} + \epsilon$) this would decrease $\pi_{2,i}$ by $\Delta\pi_{2,i}$, defined in equation (4.6).

$$\Delta\pi_{2,i} = b * \frac{L_j}{E} - b * \frac{L_j - \alpha\epsilon}{E} = \frac{b\alpha\epsilon}{E} \tag{4.6}$$

As long as the additional earnings from extracting more in period T, $\frac{\epsilon}{T}$, is smaller than the loss in $\pi_{2,i}$, taking more than the sustainable amount is strictly dominated. The same argument holds for all previous periods as well: requesting $x^{sus}_t + \epsilon$ will decrease R_{t+1} by more than ϵ, namely by $\epsilon * \alpha$ (note that by definition $\alpha > 1$). If equation (4.7) holds, sustainable extraction in all periods is an equilibrium.

$$\frac{b\alpha T}{E} \geq 1 \tag{4.7}$$

There are two important implications we can draw from equation (4.7): First, in this inequality, neither the current size of the resource $R_{j,t}$ nor the individual's request (including ϵ) show up. That is, if the inequality holds, it is never optimal to (individually) take more than the sustainable amount (ceteris paribus), irrespective of the magnitude of additional extraction. Second, note that if (4.7) holds with strict inequality, extracting less than the resource can be an equilibrium as future gains are larger than present losses from decreasing extraction. But because the model includes a maximum carrying capacity of the resource, there is no incentive to extract less than x_t^{sus} as long as $R_{j,t} = E$. In our model I focus on cases in which the parameters fulfill the inequality in (4.7) because in all other cases sustainability is not socially preferred and thus there is no need to cooperate. Hence, sustainable extraction by all players is an equilibrium in all relevant cases.

Case iii.) $0 < k_j < 1$
As argued above, the cooperative equilibrium (i.e., all players extract the sustainable amount in all periods) exists for $k_j = 1$ but does not exist for $k_j = 0$. This finding indicates that for some $\bar{k}_j \in (0, 1)$ the cooperative equilibrium exists for $k_j \geq \bar{k}_j$ and does not exist for $k_j < \bar{k}_j$. This defines $\bar{k}_j$ as the political tipping point: if this point is surpassed the sustainable equilibrium abruptly breaks down. To locate the political tipping point, consider two different strategies for player i that differ only in period T:

Strategy C: In this strategy all members of group j cooperate in period T, i.e., $x_{i,T}^C = y_{i,T} = x_T^{sus}$ (note that this includes multiple super-strategies, as for example grim trigger or tit-for-tat). This strategy implies a leftover of this group of $L_j = R_{j,T}$. I will write player i's earning U_i from playing C as indicated in (4.8). Extraction from previous periods is denoted as $X_{i,-T}$ and extraction in T is divided by T because the payoff from extraction equals average extraction (see equation (4.2)).

$$U_i(C) = X_{i,-T} + \frac{1}{T}\frac{R_{j,T}}{n}\left(\frac{\alpha-1}{\alpha}\right) + b * \frac{R_{j,T}}{E} * k_j^p \tag{4.8}$$

Strategy D: I want to investigate under which condition there are no incentives to deviate from the sustainable extraction in period T. Therefore define strategy D that differs from strategy C only in the very last period. In a first step assume that all players extract x_T^{sus} except for player i who requests as much as possible: $y_{i,T} = R_{j,T}$ (this is the most extreme case of deviating from sustainable extraction but the findings are independent of the magnitude of over-extraction and hold for all other cases as well). As in this case total request in the group is larger than the group's resource, all individuals will realize an extraction proportional to their requested amount, leading to $x_{i,T}^D = R_{j,T}^2 * (R_{j,T} + (n-1)x_T^{sus})^{-1}$. Because the resource is depleted in the last period, long-term payoff $\pi_{2,i}$ will be 0 and we can write player i's earning from playing D as shown in equation (4.9).

$$U_i(D) = X_{i,-T} + \frac{1}{T} * R_{j,T}^2 * \left(R_{j,T} + (n-1)\frac{R_{j,T}}{n}\frac{\alpha-1}{\alpha}\right)^{-1} + 0 \tag{4.9}$$

The comparison of the earnings of the two strategies will allow us to locate the political tipping point, $\bar{k}_j$, since k_j determines whether it is individually rational to deviate from the cooperative strategy C and play the defective strategy D. To make cooperation more (or at least as) attractive than (as) defection, and, hence, make cooperation an equilibrium, it has to be true that $U_i(C) \geq U_i(D)$. This is determined by extraction in the other groups: if cooperation in other groups is above or equal to the threshold $\bar{k}_j$, the inequality holds. In all other cases, the inequality does not hold and the cooperative equilibrium breaks down. The condition for the cooperative equilibrium to exist is shown in equation (4.10), from which we can directly infer the location of the political tipping point $\bar{k}_j$ as a function of p and other parameters:

$$k_j \geq \left(\left(\left(1 + \frac{\alpha - 1}{\alpha} - \frac{\alpha - 1}{\alpha n} \right)^{-1} - \frac{\alpha - 1}{\alpha n} \right) * \frac{E}{Tb} \right)^{\frac{1}{p}} = \bar{k}_j \tag{4.10}$$

Similar to equation (4.7), the result in (4.10) does not depend on the size of the current resource or potential gains from extraction, but only on externally given parameters and cooperation in other groups. Note further, that for some given $k_j < 1$ the inequality in (4.10) holds for small p, while it does not hold for large p. As we see in equation (4.10) the political tipping point is a function of the parameter p. Hence, p is crucial for reaching the political tipping point and thus for the existence or non-existence of the cooperative equilibrium. In other words, the parameter p determines the spillover between groups and thus the location of the political tipping point.

4.2.3 Social and Individual Optimality

The social optimal combination of strategies depends on the exact parameters. I am only interested in situations where cooperation in all periods by all players is Pareto optimal and exclude all other cases from the model. Hence, within-group cooperation is the socially and individually optimal equilibrium if the inequality in (4.10) holds. However, I have shown that if (4.10) does not hold, i.e., the political tipping point has been exceeded, it is individually rational to deviate from cooperation. Equation (4.10) defined the condition under which deviation is *individually* rational, assuming that all other players stick to the cooperative strategy. Since this holds true for all players, each member of the group will request as much as possible as soon as $k_j < \bar{k}_j$ which makes individual payoff smaller than indicated in (4.9). All players request the same amount so $x_{i,T} = \frac{R_{j,T}}{n}$ and player i's payoff will be smaller, as shown in (4.11).

$$U_i^*(D) = X_{i,-T} + \frac{1}{T} * \frac{R_{j,T}}{n} + 0 \tag{4.11}$$

This is not optimal on a group-level as long as k_j is high enough to ensure that $U_i(C) > U_i^*(D)$. Defection is only efficient for the group if the inequality in (4.12) does not hold.

$$k_j \geq \left(\frac{E}{nbT} * \left(1 - \frac{\alpha - 1}{\alpha}\right)\right)^{\frac{1}{p}} = \widetilde{k}_j \tag{4.12}$$

For all groups with $n > 1 + \frac{\alpha-1}{\alpha} + \frac{\alpha-1}{\alpha n}$, i.e., for all groups with $n > 2$ (or with $n = 2$ and $\alpha < 3$) it is true that $\widetilde{k}_j < \bar{k}_j$. Hence, for all $k_j \in (\widetilde{k}_j, \bar{k}_j)$ the group faces a prisoner's dilemma: it is individually rational to request as much as possible (in fact this is the dominant strategy) but this leads to a Pareto inefficient outcome.

4.3 Experiment

4.3.1 Overview

The theoretical model implies that a stronger spillover between groups (i.e., a higher value of the parameter p) makes it more likely for a group to pass the political tipping point, leading to a break-down of cooperation. However, cooperation is an equilibrium for all groups and all possible values of p, and, thus, this social optimal solution is feasible. One reason to deviate from the cooperative strategy is pessimistic beliefs: if a player expects the other groups to have a very low leftover, she has incentives to defect and extract more than the sustainable amount. Beliefs, preferences, and parameters (especially p) are in the field hard to observe or control for and the analysis of the theoretical model yields different equilibria. To test whether people cooperate or cooperation fails in such situations, I implemented the resource extraction game (REG) described in the previous section in a controlled lab experiment where we can vary the parameters, induce the long-term preferences and observe beliefs.

4.3.2 Parametrization

For the experiment I chose parameters that make the conditions given in equations (4.7) and (4.10) hold and that lead to $\widetilde{k}_j < \bar{k}_j$. These parameters are displayed in (4.13). The parameter p will differ between treatments (see below). I framed the resource as consisting of "Points", i.e., in period t the resource has a size of $R_{j,t}$ Points. The long term benefit b was also formulated in terms of Points.

$$
\begin{aligned}
E &= 90 = R_{j,1} \\
n &= 3 \\
m &= 2 \\
\alpha &= 1.5 \\
T &= 10 \\
b &= 10
\end{aligned}
\tag{4.13}
$$

The parameters imply a sustainable extraction of $R_{j,t}/9$ and, hence, in the first period $x_1^{sus} = 10$. In a cooperative equilibrium we have $x_t^{sus} = 10 \forall t \leq 10$. For $\pi_{i,2}$ I matched two groups with each other ($m = 2$), such that group A's leftover is relevant for group B's $\pi_{i,2}$ and vice versa.

Taking together the parameters in (4.13) and equation (4.10) we find the political tipping point in this setting to be located at $\bar{k}_j = \left(\frac{7}{11}\right)^{1/p}$. Using the numbers from (4.13) to solve equation (4.11) we get $\widetilde{k}_j = 0.2^{1/p}$. Since for a given $p > 0$ we have $\bar{k}_j = \left(\frac{7}{11}\right)^{1/p} > 0.2^{1/p} = \widetilde{k}_j$ players face a prisoner's dilemma when k_j is inbetween the two values. Remember that this result is independent of the current size of the group's own resource and, hence, independent of potential gains from additional extraction. However, if we assume that all players in all groups cooperate until the 10^{th} period (i.e., extract 10 units in each period) we can calculate player i's payoffs from different combinations of strategies chosen in the last period using equations

(4.8), (4.9), and (4.11):

$$\begin{aligned} U_i(C) &= 20 \\ U_i(D) &= 16.36 \\ U_i^*(D) &= 12 \end{aligned} \tag{4.14}$$

4.3.3 Set-up of the Experiment

The main experiment consisted of four parts: Part 1A, Part 1B, Part 2A, and Part 2B. Parts 1A and 1B gave participants the opportunity to become acquainted with the structure of the REG and Parts 2A and 2B established the treatment differences (see below for details). Groups did not change during the entire experiment, i.e., a group consisted always of the same three players and the same two groups were matched in all parts.

Before the experiment started players received the instructions for Part 1A.[3] In this part players played the REG with no connection to any other group and $\pi_{i,2}$ was only based on the group's own leftover and was formed according to equation (4.3). During each of the ten periods participants went through two stages. In the decision stage, players made their request on how many points they want to extract from their group's resource. If the sum of requested extraction in one period exceeded the size of the resource, each individual received a fraction of the resource proportional to her request. Afterwards the resource had a size of 0 Points for the rest of the game and players could only extract 0 Points in each period. Players could make a new decision in each period. In the decision stage participants received information on the group's resource size in the previous period, the group's total extraction in the previous period, the current size of the resource ($R_{j,t}$), and which fraction of the endowment this current resource corresponds to. In addition to that they were informed about the amount the group could extract in total to keep the resource stable (i.e., $3 * x_t^{sus}$), and the hypothetical $\pi_{i,2}$, i.e., the long term-benefit if the size of the resource was kept constant

[3]See Appendix for the instructions and screenshots of the experiment.

for the rest of the game and the group's leftover equals the current size of the resource.

After all players made their decision about how much they would like to extract, the second stage of the period began, where participants did not make any active decision. Here, a participant received information about how many points all members of the group requested, how much the own group requested in the respective period in total, and which extraction she realized in this period. Afterwards, the decision stage of the next period began. At the end of the last period players learned about their group's leftover of the resource and the composition of their payoff for this part.

In Part 1B participants played the same REG as in Part 1A, i.e., they started with a new resource of 90 Points and could make a decision on how much to request from the group's resource in each period. Similar to Part 1A there was no connection between groups in Part 1B. This part was followed by an elicitation of participants' belief about the distribution of other groups' leftover after this part (Part 1B) using a binarized scoring rule with the potential to earn additional €3 (Hossain and Okui, 2013, Burdea and Woon, 2022). In this belief elicitation I asked for the probability that a randomly chosen group's leftover was located in each out of nine intervals. This randomly chosen group could not be the own group.

Parts 1A and 1B were identical for all treatments and allowed participants to become acquainted with the structure of the REG before the following part implemented the connection between a group and its matching group.

As soon as all participants finished the belief elicitation, instructions for the following part of the experiment were displayed. Part 2A established the connection between a group and the respective matching group: participants played again the same REG as in the previous parts, but now $\pi_{2,i}$ was formed according to equation (4.4) and, hence, was potentially affected through the other group's usage of their resource. The magnitude of spillovers was determined by the parameter p that differed between treatments as follows.

The experiment implemented four treatments with differences along two dimensions: *i.)* the amount of information players received, and *ii.)* the parameter p. A summary of the four treatments is given in Table 4.3.1. As in the preceeding two parts players played the REG with an initial endowment of 90 Points. In each period they could request a fraction from the resource in the decision stage and received information about the realized extractions in the second stage of each period. In three out of the four treatments, participants received additional information on extraction decisions of their matching group. In the choice stage of each period they were (additionally to the information on the own group's actions) informed about their matching group's resource size and extraction in the previous period, the current size of the other group's resource, and the hypothetical $\pi_{i,2}$ if the own group and the other group kept their resource stable for the rest of the game (see Appendix for screenshots).

The three treatments with information on the matching group differed with respect to the parameter p, with either $p = 0$, $p = 0.5$, or $p = 1$ for one treatment (denoted hereafter as p0-treatment, p0.5-treatment, and p1-treatment, respectively). Note that in the treatment with $p = 0$ the above analysis does not apply since there is no potential political tipping point that can be reached. Hence, there was no direct payoff relevant link between the groups as the last part in equation (4.4) equals 1 in this case. However, participants in the p0-treatment still received information on their matching group's decisions.

In the fourth treatment players received no information about the size of the other group's resource or about the other group's extraction (hereafter referred to as the NoInfo-treatment). They were reminded in each period, that their $\pi_{2,i}$ was affected by another group that they can not observe. For this treatment I set $p = 0.5$.

Part 2B followed the same rules as Part 2A, i.e., all parameters, groups, and matching groups did not change. After the end of the fourth part a short questionaire on participants' age, gender, and field of study followed.

Each Point earned in the first two parts of the experiment (including the long-term benefit $\pi_{2,i}$) was converted to €0.1. Either the payoff from

Table 4.3.1: Treatments

	Parameter p	Info on matching group
p0-treatment	0	Yes
p0.5-treatment	0.5	Yes
p1-treatment	1	Yes
NoInfo-treatment	0.5	No

Part 1A or Part 1B was randomly chosen to be paid out to the participant (payoffs from the belief elicitation were always payed out, independently of the chosen part). Equivalently, either Part 2A or Part 2B was chosen to be paid, now with an exchange factor of 1 Point=€1. Each participant received a fix show-up fee of €3.

In the previous section I have shown that the political tipping point is a function of the parameter p (see equation (4.10)). Hence, for a given $k_j < 1$ a higher value of p leads to a break down of the cooperative within-group equilibrium while it would still exist if p took a smaller value. This makes the political tipping point easier to reach in treatments with a higher p and, hence, cooperation is harder in those treatments. A failure of cooperation decreases a group's leftover after the last period. Hence, we can formulate the first hypothesis:

> *Hypothesis I: Groups' leftover will be higher in the p0-treatment than in the p0.5-treatment. Leftover will be higher in the p0.5-treatment than in the p1-treatment.*

As soon as a group's matching group in the p0.5-treatment and the p1-treatment extracts too much from their resource, they will reach the political tipping point which makes cooperation (i.e., sustainable extraction) unattractive. Hence, individuals have no incentive to request sustainably as soon as the tipping point has been passed. This leads to the second hypothesis:

Hypothesis II: Extraction will increase as soon as the political tipping point has been reached.

From previous research we know that most people can be classified as pessimistic conditional cooperators (Fischbacher et al., 2001, Fischbacher and Gächter, 2010). That is, they want to cooperate only if their peers are cooperative as well. However, people significantly underestimate their peers' willingness to cooperate and thus show a lower level of cooperation when there is uncertainty about others' behavior (see the results in Chapter 2). Based on this we can formulate hypotheses III and IV:

Hypothesis III: Groups' leftover will be higher in the p0.5-treatment than in the NoInfo-treatment.

Hypothesis IV: More pessimistic individuals will cooperate less than less pessimistic players.

4.4 Results

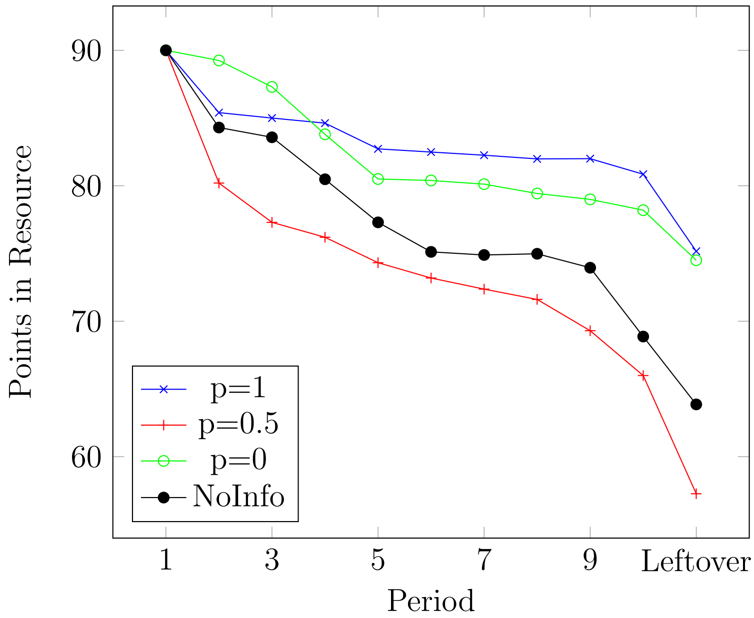
4.4.1 Sample

Data was collected between May 2022 and February 2023 at the laboratories of Heidelberg University and the University of Vienna. There were in total 360 participants and, thus, 30 groups per treatment (for each treatment there were 12 groups in Heidelberg and 18 groups in Vienna). Participants were on average 24 years old, ranging from 18 to 62 years. 49.3% of our participants were female and 97.5% were students, less than one third of our sample studied economics.[4] Subjects in the two different locations did not differ significanlty in gender, but participants in Heidelberg were younger than in Vienna (23 vs. 26 years, t-test $p < 0.01$). Sessions lastet about 70 minutes and participants earned on average €21.21. The experiment was programmed in oTree (Chen et al., 2016) and all instructions were in German.[5]

[4]One participant did not answer the survey on demographics so the numbers are based on the answers of 359 participants.

[5]German version of the instructions is available on request.

Figure 4.4.1: Average Resource Size and Leftover in Part 2A



4.4.2 Resource Size and Leftover

I predicted cooperation to be easier when the parameter p is low. This would lead to a higher $R_{j,t}$ in each period and a higher leftover for lower values of p. Figure 4.4.1 shows the average current size of the resource and leftover for the four treatments in Part 2A. Part 2B shows a similar pattern.

As expected cooperation in the p0-treatment is relatively successful: groups in this treatment left on average 74.5 Points in their resource in Part 2A (results are qualitatively the same in Part 2B) which is equivalent to 83% of their initial endowment. 76.7% of the groups in the p0-treatment left 100% of their resource after Part 2A. In line with the predictions cooperation was less successful in the p0.5-treatment where groups left on average 57.3 Points in their resource (64% of the endowment) and only 50% of the groups kept their resource perfectly stable. However, a further increase in p from $p = 0.5$ to $p = 1$ does not lead to a further decrease in cooperation but the opposite seems to be the case. Although there is a strong decline in the size of their resource in the first period, the majority of groups in the p1-treatment successfully cooperate and keep the resource nearly constant.

There is a relatively strong decline in the last period but on average groups leave 75.2 Points of their resource (84% of endowment) and 66.67% of groups' leftover equal their endowment. Table 4.4.1 shows the average number of Points groups left after Part 2A and Part 2B. Leftover after Part 2A and Part 2B are not different for the p0- and the p1-treatments (T-test, all $p > 0.1$). In both treatments with $p = 0.5$ the difference is significant on the 10%-level.

Table 4.4.1: Leftover in the four Treatments

Treatment	Leftover Part 2A	Leftover Part 2B
$p = 0$	74.5	72.1
$p = 0.5$	57.3	47.7
$p = 1$	75.2	71.9
NoInfo ($p = 0.5$)	63.9	49.3

Notes: All numbers in Points left in the resource.

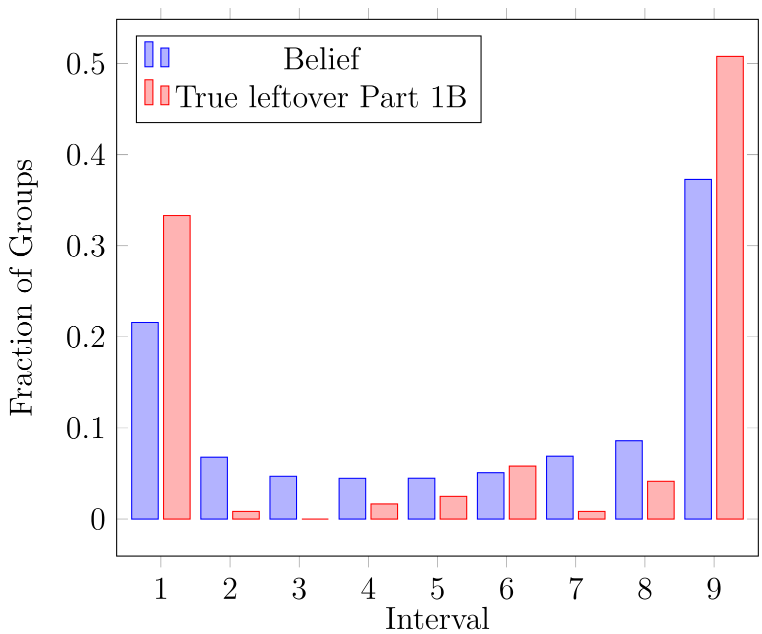
Contrary to the predictions there is no significant difference between the p0- and the p1-treatment for both parts (Mann-Whitney-U, $p > 0.1$ for both parts), and leftover is lower in the p0.5-treatment than in the p1-treatment (Mann-Whitney-U, $p < 0.1$ for Part 2A and $p < 0.05$ for Part 2B). Hence, although the difference between the p0- and the p0.5-treatment is in line with our predictions (Mann-Whitney-U, $p < 0.05$ in both parts), there is no support for Hypothesis I. Varying the parameter p has an effect on cooperation and, hence, on leftover. However, our data suggest that there is no monotonic relationship and an increase in the parameter p does not imply a systematic decrease in cooperation.

Hypothesis III stated that leftovers will be lower in the NoInfo-treatment than in the p0.5-treatment. Both treatments have the parameter $p = 0.5$ so any differences can be attributed to the lack of information. Figure 4.4.1 and Table 4.4.1 already indicate that the predicted result can not be confirmed by the data. There is no significant difference in leftovers between those two treatments and I have to reject Hypothesis III (Mann-Whitney-U, $p > 0.1$ for both parts).

4.4.3 Belief

After the last period of Part 1B participants were asked for their belief about the probability that the leftover of a randomly chosen group lies within each of nine bins (see Appendix B.3 for instructions and screenshots). From this we can infer participants' subjective belief distribution and how pessimistic or optimistic subjects are. Figure 4.4.2 shows the distribution of players' belief and the distribution of groups' true leftover.[6]

Figure 4.4.2: Participants' Belief and True Leftover after Part 1B



Notes: Interval 1: 0-10 Points, interval 2: 10-20 Points, ..., interval 9: 80-90 Points.

The true distribution of groups' leftover is bimodal: most groups either cooperate and keep their resource stable, or fail to cooperate and leave (nearly) nothing in their resource. More than 80% of the groups' leftover was either in the lowest (0-10 Points) or the highest interval (80-90 Points).

[6]Figure 4.4.2 shows the pooled results for both locations. However, subjects were significantly more pessimistic in Vienna (T-test $p > 0.01$).

Participants correctly anticipated this bimodal distribution. However, they seem to underestimate the magnitude of bimodality as they put less than 60% of weight on either the lowest or the highest interval.

If a player is extremely pessimistic, she is expected to be less cooperative and to extract more than the sustainable amount because she expects k_j^p to be low. Hence, she wants to extract as much as possible for herself. To better analyse the relationship between belief (i.e., pessimism) and extraction for each individual I form the mean and the variance of her belief distribution using the midpoint of each bin (Glas, 2020). Note that a perfectly bimodal belief distribution (i.e., 50% of weight on the first and 50% of weight on the last interval) corresponds to a mean of 45 and a variance of 1600. More optimistic participants will put more weight on the higher intervals and, hence, have a higher mean belief. Pooled over all participants there is a mean belief of 52.3 which is very close to the true mean leftover (54.2 Points).

To understand the effects of a player's belief on her extraction and payoff I run the OLS regression models $(1) - (3)$ shown in (4.15) including treatment and location dummies.

$$
\begin{aligned}
&(1)\ y_{i,1}^{rel} = \beta_0 + \beta_1 \times \mathit{optimism}_i + \beta_2 \times \mathit{uncertainty}_i + \gamma X_i^{\top} + u_i \\
&(2)\ y_{i,2}^{rel} = \beta_0 + \beta_1 \times \mathit{optimism}_i + \beta_2 \times \mathit{uncertainty}_i + \\
&\qquad \beta_3 \times \mathit{bad\_signal}_i + \beta_4 \times \mathit{bad\_signal}_i * \mathit{optimism}_i + \gamma X_i^{\top} + u_i \\
&(3)\ \pi_i = \beta_0 + \beta_1 \times \mathit{optimism}_i + \beta_2 \times \mathit{uncertainty}_i + \gamma X_i^{\top} + u_i
\end{aligned}
\tag{4.15}
$$

The dependent variable in models (1) and (2) is a player's request relative to the current size of the resource, i.e., $y_{i,t}^{rel} = \frac{y_{i,t}}{R_{j,t}}$. This relative request is more informative than $R_{j,t}$ or an individual's absolute request since sustainable (i.e., cooperative) action differs for different absolute values of $R_{j,t}$. With the chosen parameters, sustainable extraction requires a relative request of 1/3; an increase in relative request can be interpreted as uncooperative behavior. I define relative request as 1 if the current size of the resource is 0. The variable *optimism* corresponds to a player's mean belief. A higher mean belief stems from more weight on higher intervals and implies a more optimistic player. The variable *uncertainty* refers to the variance; if a player shows higher variance in her belief distribution she perceives higher uncertainty. The results of the OLS regressions are shown in Table 4.4.2, where columns (1), (2), and (3) correspond to models (1), (2), and (3), respectively. Model (1) focuses on extraction in the first period. At this point participants do not have any additional information about their matching group's performance and, hence, have to base their decision on their belief and expectation about others' behavior. The mean belief has an effect on a player's extraction decision that is significant at the 10%-level: in line with Hypothesis IV more optimistic players request less than more pessimistic players. Uncertainty (given by the variance) does not have an effect on extraction. In column (2) I look at the second period to investigate whether observing uncooperative behavior in the matching group increases own extraction. Therefore I introduce the dummy variable *bad signal* which equals 1 if the matching group extracted unsustainably in the previous period (I excluded participants from the NoInfo treatment as they can not observe any signals). The observation of uncooperative behavior has in our data no effect on players extraction. Even more pessimistic players do not react to a bad signal, indicated by the non-significance of the interaction term.

The third column of Table 4.4.2 looks at effects on participants' total payoff (π_i) in Part 2A. The resulting payoff from Part 2A is significanlty higher for more optimistic players. Both components of an individual's payoff ($\pi_{1,i}$ and $\pi_{2,i}$) take higher values if the respective player holds more optimistic beliefs.

4.4.4 Political Tipping Point

If a group observes that their matching-group extracts too much from their resource and k_j^p falls below the political tipping point, it becomes individually rational to switch from the cooperative to the defective extraction strategy. This implies an increase in extraction and, thus, a reduction of the own group's leftover. Pooled over Part 2A and Part 2B there are 120 observations on groups' leftover that can potentially be affected by reaching the political

Table 4.4.2: OLS Regression on Relative Request in the first two Periods of Part 2A

	Relative request ($y_{i,t}^{rel}$)		
	(1) $t = 1$	(2) $t = 2$	(3) π_i
optimism	-0.0004*	-0.001*	0.067***
	(0.0002)	(0.0)	(0.011)
uncertainty	0.0	0.0	-0.0
	(0.0)	(0.0)	(0.0)
bad signal		0.048	
		(0.062)	
bad signal × *optimism*		-0.0	
		(0.001)	
Constant	0.135***	0.154***	15.131***
	(0.02)	(0.04)	(1.001)
N	360	270	360
R^2	0.02	0.08	0.2

Notes: Observations on individual level. Standard error in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Model (2) excludes participants in the NoInfo treatment. Treatment and location dummies included.

tipping point: 30 groups in the p0.5-treatment, 30 groups in the p1-treatment and for each group there is one observation for Part 2A and one for Part 2B. In the p0-treatment the tipping point can never be reached since $k_j^p = 1 \forall k$ and in the NoInfo treatment participants can not know whether the point has been reached. Out of these 120 observations, the political tipping point has been reached 24 times (20% of observations). Passing this point is associated with a significantly lower leftover: while groups that did not reach the tipping point left on average 71.6 Points in the resource, those groups where the tipping point was surpassed left on average 28.7 Points (Mann-Whitney-U $p < 0.01$). I do not find such a difference in the NoInfo-treatment. This finding supports Hypothesis II as reaching the political tipping point seems to significantly affect within-group behaviour.

To further understand how groups react and adapt extraction behavior to observing cooperation rates in the matching group below the political tipping point, I run a random effects GLS regression on relative request (on the group level, i.e., $Y^{rel}_{j,t} = \frac{1}{R_{j,t}} \sum_{i=1}^{3} y_{i,t}$) in all periods in parts 2A and 2B, shown in equation (4.16).

$$Y^{rel}_{j,t} = \beta_0 + \beta_1 \times PTP_{j,t} + \gamma X^{\top}_{j,t} + v_{j,t} \tag{4.16}$$

PTP is a dummy variable that equals 1 if the political tipping point has been reached. Therefore I take the current size of the other group's resource to calculate k_j. Hence, the dummy PTP equals one if $\frac{R_{t,h}}{E} < \left(\frac{7}{11}\right)^{1/p}$, where group h is the group's matching group. The results of two specifications of model (4.16) are shown in Table 4.4.3. "$t = 10$" is an indicator for the last period that equals 1 if the respective observation is from the tenth period and 0 otherwise. *p0.5* and *vienna* are treatment and location dummies.

The regression model in column (1) confirms the findings from Figure 4.4.1 as extraction increases in later periods. However, the most important conclusion we can draw from the regression analysis is that reaching the political tipping point significantly impacts groups' extraction behavior. If a group observes that their matching group's actions alleviate long-term benefits in a way that makes cooperation unattractive, the group will react by increasing own request, i.e., cooperate less. Hence, this supports the second hypothesis: a theoretical break-down of the cooperative equilibrium leads to less cooperative behavior in the experiment.

The positive correlation between the round number and relative request seems to be mainly driven by an increase in extraction in the last period (see column (2) of Table 4.4.3). Model (2) shows that the political tipping point's effect is additionally pronounced in the last period. This implies that in some groups within-group cooperation is stable although the political tipping point has been passed and backwards induction would implicate immediate exploitation of the resource. Groups increase extraction especially in the last period, before spillovers from the matching group have payoff relevant consequences.

The results from Table 4.4.3 empirically support the predictions from the model: spillover from the matching group changes incentives and affects within

Table 4.4.3: Random-effects GLS Regression on Relative Request

	(1)	(2)
PTP	0.104***	0.075**
	(0.023)	(0.023)
$t = 10$		0.027
		(0.02)
$t = 10 \times PTP$		0.197***
		(0.032)
round number	0.008***	0.003
	(0.002)	(0.002)
p0.5	0.097*	0.094**
	(0.05)	(0.042)
vienna	0.03	0.031
	(0.051)	(0.043)
Constant	0.315***	0.334***
	(0.048)	(0.041)
# observations	1200	1200
# groups	60	60
R^2 overall	0.12	0.15
R^2 within	0.04	0.09
R^2 between	0.16	0.19

Notes: Observations on group level. Standard error in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

group cooperation. Hence, the political tipping point plays an important role in group's cooperation. As soon as it is surpassed players react by increasing their extraction and thus being less cooperative.

4.5 Conclusion

In this paper I presented a novel framework of a social ecological system with multiple local groups that are linked with each other via spillover of groups' impact on a globally shared environmental good. The state of the environment is determined by decisions made by players and the set of equilibria is determined by the state of the environment. I develop a new theoretical model from which there emerges a "political tipping point". If cooperation in other groups is high enough, there exists a cooperative, sustainable within-group equilibrium that breaks down when uncooperative extraction in other groups triggers the tipping point. In an experimental study I show that people react to the tipping point as predicted: as soon as the political tippint-point has been reached the individually requested extraction significantly increases.

With the parameter p I can externally vary the magnitude of spillover between groups. Contrary to the expectations I find the lowest cooperation rates in the treatment with $p = 0.5$, while this rate is significantly higher in the treatment with $p = 1$. One possible explanation is that if $p = 1$, there is no ambiguity about the effect of own actions on the other group and the interdependency. The two matched groups can be viewed as a single larger group with perfect alignment of preferences. However, if $p = 0.5$ the exact effects on payoffs of both, own actions and the state of the matching group's resource, can be perceived as slightly veiled and the interdependency might be uncertain. Since uncertainty has been shown to lower cooperation rates this could explain the lower leftover in this treatment (Barrett and Dannenberg, 2014).

The most prominent real-world example with a jointly preferred long-term environmental outcome that depends on actions taken in various groups is global climate change. One common argument against costly local greenhouse gas abatement is that a single country's impact on climate change is negligible. According to this argumentation, a country like Germany does not need to reduce its emissions as long as large economies, like for example China, continue emitting greenhouse gases. Countries are very heterogenous with respect to their contribution to global warming and the costs of a changing climate that they have to bear. Hence, the spillover of one country's actions on another country is not aligned and also hardly observable. My results show that in such situations, where there is a connection between groups but the magnitude of spillover can be perceived as uncertain, cooperation often fails.

The second key insight from the data is that groups decrease their level of cooperation as soon as other groups are non-cooperative and the political tipping point is surpassed. Taken together these two findings have important conclusions for environmental policy. First, non-sustainable actions do not necessarily reveal a low valuation of the environment, as we observe failure of cooperation although I induced long-term preferences (which has not been done in other common pool resource experiments). Second, countries should communicate successful environmental policies to other countries to avoid a negative feedback loop and to keep cooperation high to prevent reaching the political tipping point.

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Appendix

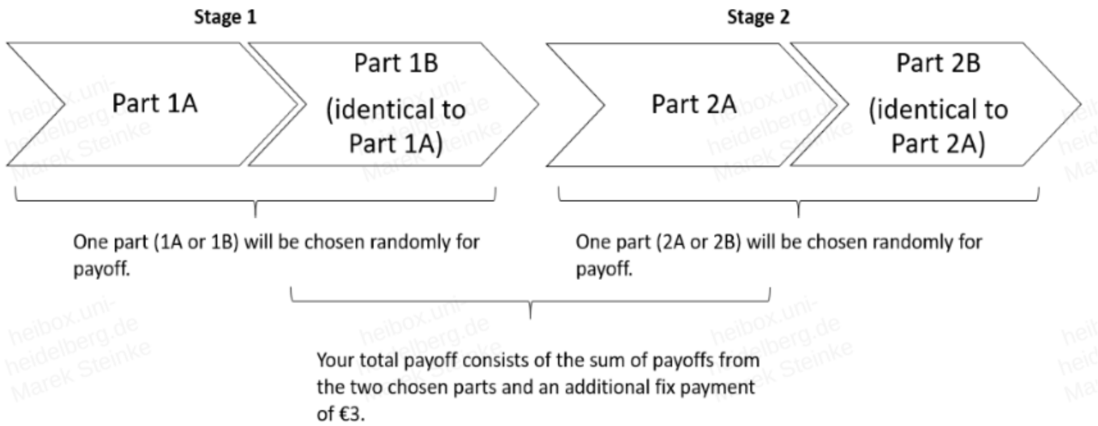
4.A Instructions

Overview

Each participant received a printed version of the following overview. All instructions were in german.

Overview of today's experiment

Structure and payoff



Groupsize

At the beginning of the experiment you will be split in groups of **3 participants**. These will not change during the entire experiment.

Baseline game

- The baseline game consists of ten periods.
- In the first period each group receives a resource of 90 Points.
- In each period the members of the group can extract Points from the resource for themselves.
- The remaining resource grows after each period by 50% but can not exceed 90 Points. The new value (after growth) will be available for the group again in the following period.
- If the group's requested extraction in a period is larger than (or as large as) the resource, the resource is exhausted in this period and devided according to the individually requested extraction.
- If the resource is exhausted it will remain at 0 Points for the rest of the game and the members of the group can only extract 0 Points.

Payoff in the single parts

The payoff (in terms of Points) in the single parts will each consist of two components:

- Component 1 corresponds to the **average extraction** of the ten periods of the baseline game.
- The computation of component 2 differs between the two stages of the game and will be displayed to you at the beginning of each stage.

After the experiment your earnings will be exchanged into Euro. The exchange rate will be displayed to you.

General Instructions

Welcome to our experiment today.
Please do not talk to each other anymore and turn off your mobile phone. Read the following instructions carefully. Raise your hand if you have a question. All other participants receive the same instructions as you.

The experiment consists of two stages, stage 1 and stage 2. The two stages consist of two parts (Part 1A and Part 1B, and Part 2A and Part 2B, respectively). In Part 1A you will play the same game as in Part 1B and in Part 2A the same game as in Part 2B. Hereafter you will find the instructions for the first stage. Your payoff will be the sum of your payoffs from the two stages and a fix amount of €3. Therefore, either Part A or Part B will be randomly chosen for the two stages. This randomly chosen Part will be displayed in the end of the experiment and payed out afterwards.

On this screen you receive the instructions for the first stage of the experiment. After the first stage you will receive the instructions for the second stage. At the beginning of the experiment you will be grouped in **groups with three participants** (named "Player 1", "Player 2", and "Player 3"), that will persist throughout the entire experiment. Hence, you will interact in all parts of the experiment with **the same two other participants**.

Part 1A

Part 1A consists of 10 rounds. In the first round of the game your group receives a commonly used resource that consists of 90 Points. In each round you can decide how many Points you want to extract from the resource for yourself. The other members of your group face the same decision. At the end of each round you (and the other members of your group) will be informed about the extraction of each member of your group. In each round you can make a new decision.

At the end of each round the remaining resource will grow by **50% but cannot grow larger than 90 Points**. In the next round the new amount will be available to your group and the members of your group can again decide how much they want to extract. In each round you will additionally be informed about the sustainable extraction. I.e., how many Points the group in total can extract maximally to keep the size of the resource constant.

If in one round the sum of requested extraction in your group is smaller than or as large as the resource, all members of the group receive in this round the requested amount. If the sum is larger than the resource all members receive an amount that is proportional to the requested extraction. In this case the resource will have a size of 0 Points in the following rounds and you can only extract 0 Points in all following rounds.

After the last round the remaining resource will again grow by 50%. This leftover (after growth) of your group will determine one component of your payoff for Part 1A (as described below).

Your payoff from Part 1A consists of two components. The first component equals your average extraction from the 10 rounds of the game. The second component of your payoff depends on the size of your leftover relative to the endowment of your group. We will calculate which fraction of the resource your group left. This fraction will be multiplied with a bonus of 10 Points. I.e., if your group leaves $X\%$ of the initial resource you and the other members of your group receive an additional payoff of $10 * \frac{X}{100}$ Points. Hence, the second component of your payoff will be larger if your group leaves a larger fraction. If your group leaves a smaller fraction this will decrease your second component. This is the second component of your payoff; your total payoff for Part 1A consists of the sum of both components and **one Point is equivalent to €0.10**.

Examples:

- In the 10 rounds of the game you have extracted on average 5 Points and after the last round 45 Points (i.e., 50%) of the resource remain. In this case you will receive (if Part 1A is chosen) for stage 1 of the experiment a payoff of $5 + 0.5 * 10 = 10$ Points. This corresponds to a payoff of 10∗€0.1=€1.00.

- In the 10 rounds of the game you have extracted on average 12 Points and after the last round 63 Points (i.e., 70%) of the resource remain. In this case you will receive (if Part 1A is chosen) for stage 1 of the experiment a payoff of $12 + 0,7 * 10 = 19$ Points. This corresponds to a payoff of 19∗€0.1=€1.90.

- In the 10 rounds of the game you have extracted on average 14 Points and after the last round 0 Points (i.e., 0%) of the resource remain. In this case you will receive (if Part 1A is chosen) for stage 1 of the experiment a payoff of $14 + 0.0 * 10 = 14$ Points. This corresponds to a payoff of 14∗€0.1=€1.40.

Part 1B

In Part 1B of the experiment you will play again with the same group the same game as in Part 1A. I.e., you will play 10 rounds and your group will be endowed in the first round with a resource of 90 Points. As in Part 1A you (and the other members of your group) will decide in each round how much you want to extract from the resource. The remaining resource will grow by 50% and will be available to your group in the next round. If your group wants to extract an amount that is larger than the resource you will receive a fraction of the resource that is proportional to your requested amount. Afterwards the resource is depleted and stays at a size of 0 Points for the rest of the game.

Your payoff has again two components. The first component equals your average extraction from the 10 rounds of the game. The second component of your payoff depends (just as in Part 1A) on the remaining resource relative to your group's initial endowment. We will calculate which fraction of the resource your group left. This fraction will be multiplied with a bonus of 10 Points. I.e., if your group leaves $X\%$ of the initial resource you and the other members of your group receive an additional payoff of $10 * \frac{X}{100}$ Points. Hence, the second component of your payoff will be larger if your group leaves a larger fraction. If your group leaves a smaller fraction this will decrease your second component. This is the second component of your payoff; your total payoff for Part 1A consists of the sum of both components and **one Point is equivalent to €0.10**. At the end of the experiment one of the two parts from the first stage, Part 1A or Part 1B, will be chosen randomly. You receive the payoff from this randomly chosen part.

Part 2A

The second stage consists as well of two parts, Part 2A and 2B. In both parts you will play again in the same group as in stage 1 the same game as in stage 1. I.e., you play over 10 rounds and your group has a resource of 90 Points available. As in stage 1 you (and the other members of your group) decide in each round how many Points you want to extract in the respective round. The remaining resource grows after each round by 50% and can be used by your group in the next round again. If in one period your group wants to extract more Points than contained in the resource you will receive in this period a fraction that is proportional to your requested fraction. Afterwards the resource is depleted and stays at 0 Points for the rest of the game.

As in stage 1 your payoff will consist of two components in stage 2 as well. The first component equals your average extraction from the 10 periods (as in stage 1). The second component of your payoff **will change** and will be calculated as follows.

The second component of your payoff will again depend on the fraction of the resource that your group leaves after the last round. Contrary to the first stage also the amount that **another group** leaves after the last round is relevant for your payoff (see below). Therefore, your group will be matched at the beginning of the game with another group. This other group faces the same decisions as you and the other group receives (just as your group) an initial resource of 90 Points. The remaining fraction of your own group and of the other group are relevant for your payoff. For this other group your group's leftover is additionally (additionally to their own leftover) relevant.

For the second component of your payoff we will calculate the fraction of the resource that your group left and the fraction the other group left of their resource. Those two fractions will be combined with a bonus of 10 Points as follows: If your group left $X\%$ of the initial resource and the other group left $Y\%$ of their initial resource, you (and the other members of your group) receive a payoff of $10 * \frac{X}{100} * \left(\frac{Y}{100}\right)^p$ **Points**. The factor p in the exponent will determine how strong the impact of the other group on your payoff is. The factor p can take values between 0 and 1 (including 0 and 1). It is chosen before the experiment and will be **the same for all groups**. Thus, the smaller the factor p, the smaller the impact of the other group on your payoff. You can find below a table that presents the results of $\left(\frac{Y}{100}\right)^p$ for different values of the fraction Y and the factor p. The value of p will be displayed further below.

Note that the second component of your payoff equals 0 if the other group depletes their resource (except $p = 0$), and that there is no difference to the first stage of the experiment if the other group sustains their resource completely. [*In each round you will now additionally be informed about the current size of the other group's resource and how much the other group has extracted in the previous period. This other group is also informed about the current size of your group's resource and how much your group has extracted in the previous round.*] [*After the last round of Part 2A you will be informed about the fraction that the other group left of their resource. This other group will after the last round be informed about how many Points your group left in the resource*].[7]

Total payoff from Part 2A equals the sum of the two components and now **1 Point equals €1**. At the end of the experiment either Part 2A or 2B will be chosen for stage 2. Your will receive your payoff from this part.

[7] The instructions in italics differed between treatments. The three treatments with information included the instructions as shown in the first squared brackets while the NoInfo-treatment received the instructions shown in the second squared brackets.

	p=0	p=0,1	p=0,2	p=0,3	p=0,4	p=0,5	p=0,6	p=0,7	p=0,8	p=0,9	p=1
Y=0	1	0	0	0	0	0	0	0	0	0	0
Y=10	1	0,794	0,631	0,501	0,398	0,316	0,251	0,2	0,158	0,126	0,1
Y=20	1	0,851	0,725	0,617	0,525	0,447	0,381	0,324	0,276	0,235	0,2
Y=30	1	0,887	0,786	0,697	0,618	0,548	0,486	0,431	0,382	0,338	0,3
Y=40	1	0,912	0,833	0,76	0,693	0,632	0,577	0,527	0,48	0,438	0,4
Y=50	1	0,933	0,871	0,812	0,758	0,707	0,66	0,616	0,574	0,536	0,5
Y=60	1	0,95	0,903	0,858	0,815	0,775	0,736	0,699	0,665	0,631	0,6
Y=70	1	0,96	0,931	0,899	0,867	0,837	0,807	0,779	0,752	0,725	0,7
Y=80	1	0,978	0,956	0,935	0,915	0,894	0,875	0,855	0,837	0,818	0,8
Y=90	1	0,99	0,979	0,969	0,959	0,949	0,939	0,929	0,919	0,91	0,9
Y=100	1	1	1	1	1	1	1	1	1	1	1

Explanation: If $p = 0.4$ and the other group left 40% of their resource (i.e. $Y = 40$), the second component of your payoff will be additionally multiplied with the factor 0.693. I.e., your payoff will equal 69.3% of the amount you would receive without the other group's impact.

In this part of the experiment we have $p = 0$.[8] This applies for your own and all other groups.

Examples (with $p = 0$):

- After the last round there are 45 Points (i.e., 50%) of your group's resource left. The other group leaves 90 Points (i.e., 100%). Hence, the second component of your payoff in Part 2A equals $10 * 0.5 * 1^0 = 5$ Points.
- After the last round there are 63 Points (i.e., 70%) of your group's resource left. The other group leaves 45 Points (i.e., 50%). Hence, the second component of your payoff in Part 2A equals $10 * 0.7 * 0.5^0 = 7$ Points.
- After the last round there are 90 Points (i.e., 100%) of your group's resource left. The other group leaves 0 Points (i.e., 0%). Hence, the second component of your payoff in Part 2A equals $10 * 1 * 0^0 = 10$ Points.

[8] The shown instructions are taken from the p0-treatment. In the other treatments the numbers are changed accordingly.

Note that as in stage 1 this second component will be added to the first component of your payoff (which equals your average extraction).

Part 2B

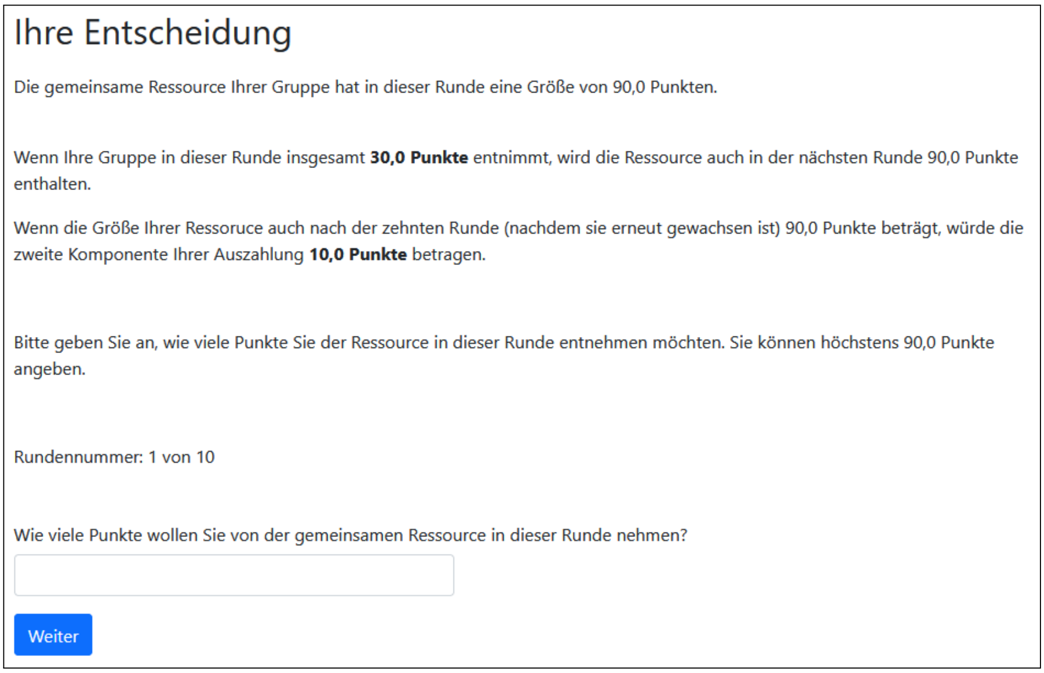
In Part 2B of the experiment you will play again with the same group as in the previous parts the same game as in Part 2A. The same other group as in Part 2A is relevant for the second component of your payoff (additionally to your own). In this part of the experiment p **will take the same value** as in Part 2A and is displayed below. Below you can also find the same examples as in the instructions for Part 2A and the table that shows the results of $\left(\frac{Y}{100}\right)^p$ for different values of the fraction Y and the parameter p. At the end of the experiment one of the two parts (Part 2A and Part 2B) will be randomly chosen. You receive your payoff from this part.[9]

Note that as in stage 1 and Part 2A this second component will be added to the first component of your payoff (which equals your average extraction).

[9]The same table and examples as in Part 2A were displayed here.

4.B Screenshots

Decision Screen in Stage 1



Ihre Entscheidung

Die gemeinsame Ressource Ihrer Gruppe hat in dieser Runde eine Größe von 90,0 Punkten.

Wenn Ihre Gruppe in dieser Runde insgesamt **30,0 Punkte** entnimmt, wird die Ressource auch in der nächsten Runde 90,0 Punkte enthalten.

Wenn die Größe Ihrer Ressoruce auch nach der zehnten Runde (nachdem sie erneut gewachsen ist) 90,0 Punkte beträgt, würde die zweite Komponente Ihrer Auszahlung **10,0 Punkte** betragen.

Bitte geben Sie an, wie viele Punkte Sie der Ressource in dieser Runde entnehmen möchten. Sie können höchstens 90,0 Punkte angeben.

Rundennummer: 1 von 10

Wie viele Punkte wollen Sie von der gemeinsamen Ressource in dieser Runde nehmen?

Weiter

Your decision

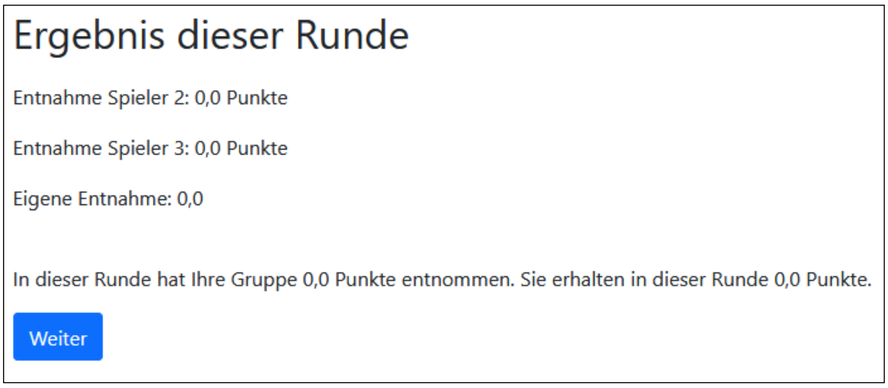
The common resource of your group has in this round a size of 90.0 Points.
If your group extracts in this round in total **30.0 Points** the resource will contain 90.0 Points in the next period.
If after the tenth period (after it grew again) the resource has a size of 90.0 Points the second component of your payoff would equal **10.0 Points**.

Please indicate how many Points you want to extract from the resource in this round. You can indicate maximally 90.0 Points.

Round number: 1 of 10

How many Points do you want to extract from the common resource in this round?
[*Participant's answer*]
[*Continue button*]

Results Screen in Stage 1



Results of this round

Extraction Player 2: 0.0 Points

Extraction Player 3: 0.0 Points

Own extraction: 0.0

In this round your group extracted 0.0 Points. You receive in this round 0.0 Points.

Belief Elicitation in Part 1B

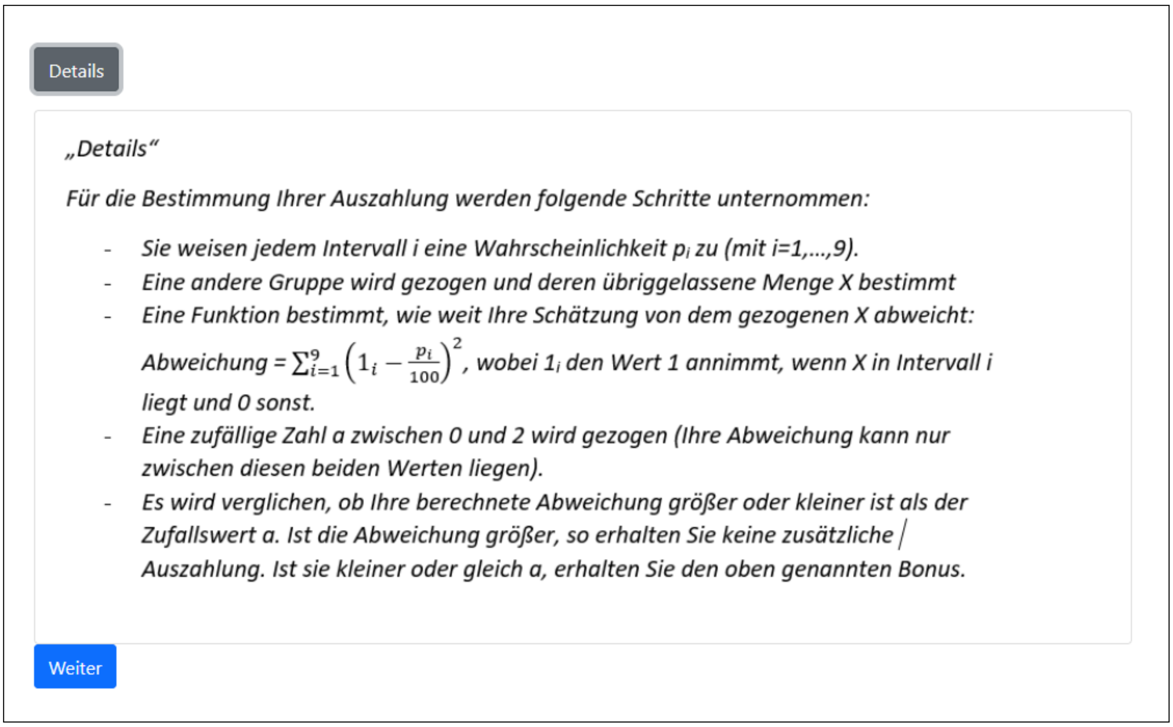
Bevor Abschnitt 2 beginnt, haben Sie noch die Möglichkeit, 3€ zusätzlich zu verdienen. Dafür geben Sie unten Ihre beste Schätzung darüber ab, wie viel ihrer ursprünglichen Ressource die **anderen** Gruppen am Ende von Teil 1B (nach der letzten Runde, nachdem die Ressource erneut gewachsen ist) übriggelassen haben.

Dazu schätzen Sie bitte, wie wahrscheinlich es ist, dass eine zufällig ausgewählte Gruppe eine bestimmte Menge X am Ende von Teil 1 übriggelassen hat. Hierfür ordnen Sie den folgenden neun Intervallen je eine Wahrscheinlichkeit (in Prozent) zu. Fragen Sie sich also, wie wahrscheinlich es ist, dass die übriggelassene Menge dieser zufällig gezogenen Gruppe in dem jeweiligen Intervall liegt. Bei dieser zufälligen Gruppe kann **nicht Ihre eigene Gruppe** gezogen werden.

Der Mechanismus, mit dem bestimmt wird, ob Sie die zusätzliche Auszahlung erhalten oder nicht, ist komplex. Für Sie ist wichtig, dass es am besten ist, Ihre wahre Schätzung abzugeben. Falls Sie die Details wissen wollen, klicken Sie unten auf „Details".

Die Wahrscheinlichkeiten die Sie angeben, müssen sich zu 100% aufaddieren. Bitte geben Sie nur ganze Zahlen an.

Intervall	**Wahrscheinlichkeit (in Prozent)**
0-9,99 Punkte	
10-19,99 Punkte	
20-29,99 Punkte	
30-39,99 Punkte	
40-49,99 Punkte	
50-59,99 Punkte	
60-69,99 Punkte	
70-79,99 Punkte	
80-90 Punkte	



Details

„Details“

Für die Bestimmung Ihrer Auszahlung werden folgende Schritte unternommen:

- *Sie weisen jedem Intervall i eine Wahrscheinlichkeit p_i zu (mit i=1,...,9).*
- *Eine andere Gruppe wird gezogen und deren übriggelassene Menge X bestimmt*
- *Eine Funktion bestimmt, wie weit Ihre Schätzung von dem gezogenen X abweicht:* *Abweichung =* $\sum_{i=1}^{9}\left(1_i - \frac{p_i}{100}\right)^2$, *wobei 1_i den Wert 1 annimmt, wenn X in Intervall i liegt und 0 sonst.*
- *Eine zufällige Zahl a zwischen 0 und 2 wird gezogen (Ihre Abweichung kann nur zwischen diesen beiden Werten liegen).*
- *Es wird verglichen, ob Ihre berechnete Abweichung größer oder kleiner ist als der Zufallswert a. Ist die Abweichung größer, so erhalten Sie keine zusätzliche Auszahlung. Ist sie kleiner oder gleich a, erhalten Sie den oben genannten Bonus.*

Weiter

Before stage 2 starts you have the opportunity to earn additional €3. Therefore, you can enter below your best guess on how much of their resource the other groups left at the end of Part 1B (after the last round and after growth).

Please indicate your perceived likeliness that a randomly chosen group has left a certain amount X at the end of stage 1. To do so, please indicate a probability (in percent) for all of the following nine intervals. Hence, you should ask yourself, how likely the leftover of the randomly chosen group lies within the respective interval. The randomly chosen group **can not be your own group**.

The mechanism that determines whether you receive the additional payoff is complicated. Most importantly, it is in your best interest to declare your true belief. If you want to see the details please click on “Details” below. The probabilities that you enter must add up to 100%. Please enter only integers.

Interval	**Probability (in percent)**
0 - 9.99 Points	[*participant's answer for this interval*]
10 - 19.99 Points	[...]
20 - 29.99 Points	[...]
30 - 39.99 Points	[...]
40 - 49.99 Points	[...]
50 - 59.99 Points	[...]
60 - 69.99 Points	[...]
70 - 79.99 Points	[...]
80 - 90 Points	[...]

[*Details button*]

The calculation of your payoff takes the following steps:

- You declare for each interval i a probability p_i $(i = 1, \ldots, 9)$.

- Another group is randomly chosen and their leftover X is determined.

- A function calculates how much your guess deviates from the chosen X:

$$Deviation = \sum_{i=1}^{9} \left(1_i - \frac{p_i}{100}\right)^2.$$

  1_i equals 1 if X lies within interval i and 0 otherwise.

- A random number a between 0 and 2 is chosen (your deviation can only lie between these two numbers).

- The computer compares your deviation with the random number a. If the deviation is larger than a you will not receive the additional payoff. If it is smaller than a you receive the bonus.

[*Continue button*]

Decision Screen in Stage 2

Ihre Entscheidung

Übersicht über die Größe der Ressource Ihrer und der anderen Gruppe:

Eigene Ressource letzte Runde:	90,0 Punkte
Entnahme eigene Gruppe letzte Runde:	0,0 Punkte
Eigene Ressource aktuelle Runde:	90,0 Punkte (entspricht 100,0% der Anfangsausstattung)

Ressource andere Gruppe letzte Runde:	90,0 Punkte
Entnahme andere Gruppe letzte Runde:	0,0 Punkte
Ressource anderer Gruppe aktuelle Runde:	90,0 Punkte (enspricht 100,0% der Anfangsausstattung)

Wenn Ihre Gruppe in dieser Runde insgesamt **30,0 Punkte** entnimmt, wird die Ressource auch in der nächsten Runde 90,0 Punkte enthalten.

Wenn die Größe Ihrer Ressource auch nach der zehnten Runde (nachdem sie erneut gewachsen ist) bei 90,0 Punkten bleibt und die Größe der Ressource der anderen Gruppe auch nach der zehnten Runde (nachdem sie erneut gewachsen ist) bei 90,0 Punkten liegt, würde die zweite Komponente Ihrer Auszahlung 10,0€betragen.

Bitte geben Sie an, wie viele Punkte Sie der Ressource in dieser Runde entnehmen möchten. Sie können höchstens 90,0 Punkte angeben.

Rundennummer: 2 von 10

Wie viele Punkte wollen Sie von der gemeinsamen Ressource diese Runde nehmen?

Weiter

Your decision

Overview over the size of the resources of your own and the other group:

Own resource last round: 90.0 Points

Extraction own group last round: 0.0 Points

Own resource current round: 90.0 Points (corresponds to 100% of the initial endowment)

Other group's resource last round: 90.0 Points

Extraction other group last round: 0.0 Points

Other group's current resource: 90.0 Points (corresponds to 100% of the initial endowment)

If your group extracts in this round in total **30.0 Points** the resource will contain 90.0 Points in the next period.
If after the tenth period (after it grew again) the resource of your groups has a size of 90.0 Points and the resource of the other group has a size of 90.0 Points the second component of your payoff will equal €10.0.

Please indicate how many Points you want to extract from the resource in this round. You can indicate maximally 90.0 Points.

Round number: 2 of 10

How many Points do you want to extract from the common resource in this round?
[*Participant's answer*]
[*Continue button*]

Chapter 5

Conclusion and implications

This dissertation focussed on questions concerning cooperation in environmental decisions in the presence of preferences for long-term environmental stability. I took a threefold approach to shed light on different aspects of these situations. In a first step, we ran a household-level online survey experiment to elicit the magnitude and determinants of people's willingness to give up current consumption if this helps to enhance the state of the environment in the future. Based on this, I further zoomed-in on two aspects of cooperation dilemmas where people care about long-term stability of a renewable resource. More precisely, in a second and third step I established a link between groups via a shared long-term outcome where groups act either sequentially or contemporaneously.

A first key result comes from the study on people's willingness to pay (WTP) for environmental stability. We used an online survey experiment with a between subject design to elicit the share of their income that participants are willing to give up in order to keep the environment in general stable, including various aspects like the climate or biodiversity. Treatments varied along two dimensions: (*i*) the time-horizon of when the environmental benefits would accrue (in the next few years vs. in the next centuries, mostly far after the participant's lifespan), and (*ii*) the presence or absence of a cooperation problem that arises from uncertainty about other's WTP.

We could show that people are willing to give up a substantial fraction of their income for environmental stability (more than 8% in all treatments). The WTP did not significantly vary with the time horizon: participants of the treatments with the long-run time horizon stated no significantly different WTP than those in the treatments with a short-run time horizon. Hence, we can conclude that people hold an intrinsic valuation of the environment, even for environmental stability far beyond the own lifespan. However, adding a cooperation problem through uncertainty about other's WTP significantly decreases WTP. The results on the beliefs that people hold about other's WTP can explain the lower WTP in the treatments with uncertainty. Respondents of the study tend to underestimate their peers' willingness to give up current income for future environmental benefits. Since they base their own decision on this (biased) belief, the share that people are willing to give up decreases starkly in the presence of a cooperation problem arising from uncertainty about others' alacrity to give up part of their income. That is, most participants can be described as pessimistic conditional cooperators who hold in principle strong preferences for the (far) future and are willing to give up a substantial fraction of own income to reach certain environmental goals. However, they base their own WTP decision on their belief about other's WTP that tends to be downwards biased.

Based on the results of the survey experiment I investigated the role of intertemporal aspects in the cooperation problem when long-term preferences exist. I induced those preferences in a lab experiment on a multi-period resource extraction game with a renewable resource. In each period players could make a decision on how much of the resource they want to extract for themselves; the remainder was multiplied by a commonly known growth factor before players could again make a new decision in the next period. While in one treatment control over the resource was maintained by one group, there was a switch in control over the resource between groups in the second treatment. For the first five periods one group could use the resource, then it was handed over to another group that could extract from the resource over multiple periods. Afterwards the remainder was handed back to the first group again. This intertemporal link did not affect the existence of a sustainable, cooperative (within-group) equilibrium.

However, the resulting data show that the existence of a potentially destructive future group that takes over the resource hinders cooperation in the present, and groups in the treatment with switching control extracted less sustainably than groups that maintained control. Although everybody holds preferences for stability of the resource during the entire game (and everybody knows that others face the same incentives), the resource is exploited at an early stage if control over the resource is taken over by future groups.

Situations with long-term environmental goals and changing control over environmental decisions abound often in the real world. This could be, for example, observed in the role of the United States in the Paris Agreement.

After Donald Trump won the presidential elections he withdraw from the agreement that the preceeding government has signed and agreed to. However, within the first few days of his presidency, Joe Biden returned to the Paris Agreement.

Not only changing governments, like in the US or recently in Brazil, lead to a switch in control over an environmental good or resource. There is also a potential conflict between generations. If members of current generations hold pessimistic beliefs about future generations' environmental attitudes, they will expect them to act unsustainably. That is, current effort put into protecting the environment is expected not to lead to the commonly preferred goal of long-term environmental stability. Although future generations may hold strong preferences for long-term environmental stability, pessimistic beliefs of current generations are sufficient to reduce or even vanish incentives for current generations to cooperate and make sustainable decisions.

Effective environmental policy should incorporate the intertemporal dimension to encounter potential failure of cooperation. Intertemporal commitment devices could help by making future unsustainable decisions less attractive and, thus, potentially enhancing beliefs of current decision makers about future decision makers' actions. These could also include prices for emitting greenhouse gases that will rise in the future, or establishing so called *climate clubs*, because potential withdrawal by future desion makers is associated with high costs for them. This both would increase current groups' perceived likelihood that future groups make sustainable decisions and thus, for example, global warming can be reduced through effective climate actions in the present.

In the third step of this thesis I took the intertemporal aspect out and focused on within-group cooperation if benefits from cooperation depend on other contemporaneous groups as well. This study was based on the previous studies as it induced long-term preferences and investigated cooperation in a multi-period resource extraction game. In contrast to the previously described experiment, the groups did not act sequentially but contemporaneously and were linked by a commonly shared long-term benefit that is determined by all groups' actions. I.e., there is a spillover between groups of the effect of a group's actions on other groups' long-term outcome. If other groups do not act sustainably long-term benefits can not accrue anyways, irrespective of own decisions. Hence, if cooperation levels of other groups fall below a certain threshold, short-term profits of unsustainable extraction will outweigh long-term benefits of conserving the resosurce. I call this threshold the *political tipping point*: if cooperation levels stay above this point, there exists a cooperative and sustainable within-group equilibrium. If cooperation rates of other groups fall below this point, the cooperative equilibrium breaks down.

Through the choice of parameters I could vary the magnitude of between-group spillover and, hence, the location of the political tipping point. This determines how high cooperation rates in other groups have to be for the cooperative within-group equilibrium to exist. Based on this model I ran a lab experiment with four treatments that differed with respect to the information players received and the magnitude of spillover between groups. I could not find a monotonic relationship between magnitude of spillover and cooperation rates. Cooperation was successfull when there was no spillover or spillover was very strong. I found lowest cooperation rates in treatments with a moderate between-group spillover.

As predicted by the model the political tipping point playes a crucial role for within-group cooperation. As long as other groups' cooperation levels stay above this point, players tend to choose the social optimal cooperative equilibrium. However, if the political tipping point was surpassed this equilibrium vanishes and cooperation rates significanlty decreased.

The model and the experiment including spillover between contemporaneous groups can help analyse numerous social environmental problems. For example, one argumentation against cutting greenhouse gas emissions in a country like Germany refers to high emissions in other countries like, for example, China. Following this argumentation, lower emissions in Germany are negligible and will not contribute to a decrease of global warming. This argument is captured by my research: other groups (are perceived to) act unsustainably and, hence, within-group cooperation means forgoing consumption without any future benefits. However, taking together all three studies has two key implications. First, beliefs about other groups (e.g., other countries) might be downwards biased. Second, following the argumentation above implies a dominance of non-cooperation due to other groups' behaviour. However, own group's actions are observed by other groups that will in turn react to potentially changing incentives by reducing own rates of cooperation even more. The consequence will be a negative feedback loop leading to a socially undesired environmental outcome. This can be moderated by emphasizing the common aim of long-term environmental stability and the allignment of preferences, and taking a leading role in ambitious climate action to keep cooperation levels above the political tipping point.

In sum, the aim of my dissertation was to get a better understanding of people's WTP for long-term environmental benefits and factors that affect cooperation in the presence of these long-term preferences. The results highlight the importance of incorporating the inter- and intratemporal dimension of social cooperation problems in environmental policies. More precisely, policies within a country can affect policy choices in other countries. Hence, countries that take a leading role with ambitious environmental policies could have a larger impact than, for example, the own greenhouse gas abatement. Furthermore, policies that include incentives for future groups to act sustainably can enhance current rates of cooperation. If own actions can make a difference people are willing to forgo short-term consumption in order to preserve the environment for future generations.