Climate Policy Commitment Devices

Sebastian Dengler[a], Reyer Gerlagh[a,b] , Stefan T. Trautmann[a,c], Gijs van de Kuilen[a]

Version: October 16, 2016

Preliminary version – do not circulate or cite!

Abstract

We develop a dynamic resource extraction game that mimics the global multi-generation planning problem for climate change and fossil fuel extraction. We implement the game under different conditions in the laboratory. Compared to a 'liberal' baseline condition, we find that policy interventions that provide a costly commitment device or reduce climate threshold uncertainty reduce resource extraction. We also study two ethics conditions to assess the underlying social preferences and the viability of ecological dictatorship. Our results suggest climate-change policies to focus on investments that lock the economy into carbon-free energy sources.

[a]Tilburg University; [b]CREE - Oslo Centre for Research on Environmentally friendly Energy; [c]University of Heidelberg. We thank seminar participants at ZEW Mannheim for helpful comments.

Introduction

Reducing fossil fuel use is a major component of climate policy. Yet the economic mechanisms for exhaustible resources amplify the coordination difficulties for the public good. Effective climate policy requires coordination both between countries, and over time between generations, because the exhaustible resource characteristics of fossil fuels tend to annul unilateral action (cf. Karp 2015 and references therein). A decrease of fuel demand induces increasing demand by others, both by other countries as emphasized in the carbon leakage literature (Michielsen 2014), and over time as reported in the green paradox literature (Sinn 2008, Gerlagh 2011). Policy makers who are unaware of these challenges tend to develop too optimistic plans. Early climate targets are subsequently relaxed. The lack of commitment is especially problematic if climate change is uncertain, and the threshold for a 'catastrophe' is unknown (Barrett and Dannenberg 2012, Gerlagh and Michielsen 2015). There is an abundant literature on the *international* coordination problem, mostly presenting a pessimistic free-rider perspective (Barret 1994). The current paper focusses on the *intertemporal* coordination problem. Recently, some more optimistic analyses suggest democratic rules (Hauser et al. 2014) and investments in renewable energy as a commitment device as solutions of the dynamic problem (Holtsmark and Midttomme 2015, Harstad 2015). We contribute to this literature, showing in the context of an intertemporal resource extraction dilemma that, indeed, a commitment device to reduce future resource demand can help to implement resource conservation as a second-best strategy. That is, the commitment device is costly, meaning that its use is inefficient – a waste of welfare – from a first-best planner's perspective. Yet, in the context of a strategic interaction between generations, it helps to improve the outcome compared to a context where this commitment device is not available.

We develop a simple 3-player 3-period sequential resource extraction game in the spirit of Erev and Rapoport (1990) and Budescu et al. (1992). The game mimics the essential characteristics of the climate change, fossil fuel resource-planning problem through four key features. First, players in the game can exploit or conserve a resource, but conservation by one player does not prevent exhaustion by others. Second, resource conservation is a public good. Each generation values its own consumption, but also derives utility from contributing to a stable climate. We describe the public good feature through a payoff for all players that depends on both their own resource extraction and the end-of-game resource conservation as in Schmidt et al. (2011), Neubersch et al. (2014) and Gerlagh and Michielsen (2015). Third, the public good is uncertain, so that the benefits from resource conservation are not precisely known (the threshold for climate catastrophe is uncertain). This is an important difference with Hauser et al. (2014), who have a perfectly known sustainability threshold. The certainty of the climate threshold has been found to have effects on cooperation (Barret and Dannenberg 2012, Gerlagh and Michielsen 2015), and will be a policy variable in the current study. Fourth, the game is played sequentially, so that strategies are asymmetric. Early players must base their decisions on expectations regarding future strategies by other players and the consequential conservation outcomes. Later players can condition their actions on earlier choices by the other players.

We study the game's outcomes in an incentivized laboratory experiment under different conditions. A benchmark condition called *Liberal* reflects a democratic business-as-usual scenario. Two conditions refer to potential policy interventions. Policy condition *Certainty* eliminates uncertainty about the catastrophe threshold, resembling an increased funding of research to improve climate change predictions. This condition resembles the features studied in more detail by Barrett and Dannenberg (2012). Importantly, in our design we impose a conservative assessment, with climate catastrophe resulting for any non-zero degree of exploitation of the resource, i.e., the Certainty condition provides a theoretically strictly worse environment. However, in equilibrium, the threat of climate catastrophe leads to full resource conservation. Policy condition *Solar* introduces a costly commitment device resembling the development of renewable energy, based on a recently developing literature emphasizing the commitment problem as one of the key-elements of effective climate policy (Gerlagh and Michielsen 2015, Harstad 2015, Holtsmark and Midttomme 2015). In the Solar condition, it is the choice of the first generation player that determines whether the commitment device will be used. The commitment is intertemporal; we do not study intra-temporal commitment mechanisms, e.g. public choices enforced through voting (Hauser et al. 2014).

We also consider two conditions that investigate the ethical aspects of the public good dilemma in resource conservation. Condition *Dictator* introduces commitment through dictatorship of the first player. The first generation player thus has the possibility to become a benevolent ecological dictator installing full resource conservation to the benefit of future generations. However, he may also be induced to exploit the resource for his own benefit, restricting only future generations. The trade-off faced by the dictator reflects the current discussion on the desirability of ecological dictatorship (Stehr 2015). Condition *Rawls* introduces a 'veil of ignorance:' when choosing their strategies, players are not yet aware of their position in the sequential game. It aims to move the perspective of the decision maker away from individual to group benefits, i.e., considering the outcome of all generations jointly. These two conditions provide empirical insight into the trade-off between own benefits and group benefits, which is inherent to the intergenerational resource extraction dilemma. Note that meaningful labels are used for convenience in this manuscript but were not part of the experiment.

The experiment has three stages. In the first stage subjects play each condition exactly once in groups of 3 players without receiving feedback on outcomes. This allows for within-person comparison of behavior across the different institutions. In the second stage, players vote for their preferred condition under a simple majority rule with tie breaking, and play the selected game once. Here we aim to understand the perceived legitimacy of the different institutions and how it affects endogenous institutional choice (Sutter et al. 2002), e.g., even if dictatorship yields better social outcomes than the liberal condition, it may not be acceptable as an institution. In the third stage, players are randomly regrouped. Each group plays one of the conditions repeatedly for six rounds, allowing players to accumulate experience. We thus observe whether a condition directly implements a certain level of resource conservation, or whether learning and experience of realized outcomes are crucial for players to understand the underlying mechanisms.

We observe the following main results. The benchmark condition (Liberal) leads to almost full resource extraction. An exactly-known threshold for climate catastrophe (Certainty) reduces resource use, consistent with earlier findings in the context of international cooperation (Barrett and Dannenberg 2012). The effect becomes more pronounced with experience. The costly commitment device (Solar) reduces resource use most in the initial stage. However, its effect gets less pronounced with experience. Despite its wasteful investment cost, it increases social welfare compared to the liberal condition. The two ethics conditions show the importance of experience for the trade-off that participants make between self-centered profit maximization goals and a global view on joint benefits. In the first stage, Dictator resource conservation is indistinguishable from Liberal. With experience, dictatorship allows for a modest degree of improvement in outcomes over Liberal. Self-centered choices still play an important role in this condition though. Rawls is more successful in implementing resource conservation. However, even after learning, no full conservation emerges. Rawls thus provides an upper limit of what a policy intervention may potentially attain, given some learning opportunities.

Our findings support investments into renewable energy as a second-best climate policy strategy to reduce expected future fossil fuel use. Investments today affect future climate decisions. A sophisticated decision maker has reason to invest in clean energy sources, as these make it easier for future decision makers to continue a climate protection program. Such investments pose large upfront costs, and future profits may not fully pay back for these costs. Yet, even when markets may suggest that such investments are too costly, our study points to the opposite direction. Subsidies or other instruments that increase clean energy innovations are an essential part of an effective decision maker's toolkit.

The resource-extraction game

The resource extraction game models the behavior of three agents in a sequential resource extraction setting. We assume that the resource stock S_t develops according to the dynamic equation

$$S_{t+1} = S_t - R_t, \tag{1}$$

where $R_t \in \{0,1\}$ denotes exploitation in period t (by agent t), and $S_1 = 2$. S_4 denotes the final stock, which determines whether a stable climate can be attained. Each player receives direct benefits from resource exploitation, but also from resource conservation through climate protection. Payoffs are given by

$$V_t = 6R_t + 8C, \tag{2}$$

where V_t denotes the payoffs to the agent living in period t, and $C \in \{0,1\}$ is an indicator for a stable climate.

The payoff structure presents a subtle difference in preferences between generations in the climate change context. Each generation gives a higher weight to its own consumption vis-à-vis the consumption of next generations; such myopic preferences are typical for descriptive models of intertemporal allocation problems. The first term in (2) represents a simplified version of these: it associates zero weight to the benefits of resource extraction by next generations. Note that our empirical data will inform about the importance of any direct (and unspecified) altruism towards the other parties in the context of the current dilemma. Such attitudes would be relevant if the current generation forgoes benefits of extraction in favor of the next generation, at its own expense after accounting for long-term benefits. The payoff function specifies that generations are not fully myopic. They are concerned about far-future outcomes of their decisions. In climate-economy models, the positive weight for long-term outcomes can be modelled through quasi-hyperbolic time discounting (Gerlagh and Liski 2012), or through a positive weight for the long-term future through an additional payoff (Chichilnisky 1996, Gerlagh and Michielsen 2015). The second part of the payoff function captures the generation's dislike to add risk to the climate system by increasing the atmospheric CO2 content, representing decision making under scientific uncertainty. The altruism towards far-future generations is explicitly modelled in the payoffs through the stable climate indicator. That is, we do not measure home-grown altruism regarding far off generations, but aim to study intertemporal cooperation *conditional* on the presumed empirical relevance of such altruism, using induced preferences.

The payoff structure constructs a paternalistic view in which the first generation prefers a stable climate, but also likes to reap the gains from fossil fuel use and to shift costs of achieving a climate targets on to the second generation. The second generation also appreciates a stable climate, but as well the own gains from fossil fuel use. This set up constructs an intertemporal dilemma. Each generation would like to commit the next generations to abandon fossil fuel use, but without commitment device, the accumulation of short-term exploitation gains results in long-term climate damages.

The benchmark (Liberal) game

In the liberal game, there are no restrictions on the agents' exploitation choices. If all resources are conserved, a stable climate is ensured. If one of the two resource units is conserved, the probability of a stable climate is 50%. If the resource is fully exploited a stable climate is impossible, i.e., $C = 0$.

$$S_4 = 0 \Rightarrow C = 0 \tag{3}$$

$$P(C = 1|S_4 = 1) = \tfrac{1}{2}, \tag{4}$$

$$S_4 = 2 \Rightarrow C = 1 \tag{5}$$

Thus, the expected climate variable is linear in the final resource stock: $\mathbb{E}(C) = \frac{1}{2}S_4$. It follows that for the third player, expected payoffs are maximized by extracting the resource:

$$\mathbb{E}(V_3) = 6R_3 + 4S_4 = 4S_3 + 2R_3 \tag{6}$$

Through backward induction, it is clear that for each player it is optimal to extract the resource if given the opportunity. In contrast, the expected group payoff is maximized by full resource conservation:

$$\mathbb{E}(V_1 + V_2 + V_3) = 6R_1 + 6R_2 + 6R_3 + 24\mathbb{E}(C) = 12 - 6S_4 + 12S_4 = 12 + 6S_4 \tag{7}$$

The expected group payoff increases in conservation S_4, but resource extraction is individually optimal for agents who are only concerned about their own payoffs as given by (2). For the earlier players, resource conservation is specifically risky, as it leaves the opportunity for the subsequent players to extract the resource, not leaving any reserve at the end, so that good deeds are not paid back.

Two policy conditions

We study two policy conditions that aim to overcome coordination failure. First, the *Certainty* condition assumes that scientific research has sufficiently progressed to pinpoint the precise catastrophe threshold. As a conservative assessment, we assume that the threshold is found to be at the lower end. That is, a catastrophe is certain whenever any part of the resource is exhausted:

$$C = \begin{cases} 1 \; if \; S_4 = 2 \\ 0 \; if \; S_4 < 2 \end{cases} \tag{8}$$

In this case, exploiting the first unit is more harmful than in the above setting with uncertainty, while there is no additional harm from exploiting the second unit. For the third player, the individually rational conservation decision depends on the inherited resource stock. If two resource units are inherited, conservation leads to payoff of 8 units, while extraction pays 6 units. Thus, conservation is individually rational. If one resource unit is inherited, a stable climate is unattainable and resource extraction is the superior strategy. By backward induction, one can see that full resource conservation is the unique Nash equilibrium, but it requires a supporting belief structure of the first two players in the conservationist strategy by the subsequent players. Empirically, it may be easier to maintain cooperation in the absence of uncertainty (cf. Barret and Dannenberg, 2012).

The second policy condition, *Solar*, concerns an investment $I_1 \in \{0,1\}$ of the first player into a technology (e.g., renewables) that makes future resource exploitation redundant. As in the liberal game, however, there exists uncertainty about the threshold for climate catastrophe. We model the treatment such that an up-front cost can be incurred by agent 1, which fixes future exploitation at zero for agent 2 and 3 ($R_2 = R_3 = 0$); agent 1 can still exploit the resource though. The investment is costly for agent 1, reducing payoffs by 1 unit:

$$V_1 = 6R_1 - I_1 + 8C \tag{9}$$

In the *Solar* condition agent 1's expected payoffs are maximized by exploiting the resource and simultaneously investing in the renewable, with a probability of a climate catastrophe of 50%.

We emphasize that both policy interventions restrict the opportunity set. Certainty reduces expected payoffs in the case of exactly one resource unit being extracted. Employing the Solar option requires a wasteful investment cost. The important empirical question we aim to answer in this paper is whether in the presence a conflict between individual and social rationality these policies can implement better outcomes despite the restricted opportunity sets.

Two ethical perspectives

Compared to the benchmark *Liberal* condition, the policy conditions *Certainty* and *Solar* change the technology of the game described in equations (1)-(7). We now define two ethical conditions that do not change technology compared to the benchmark, but that change the mapping between the players, decisions, and payoffs. Again, there is uncertainty about the climate threshold.

The *Dictator* condition implements the decisions by the first player for all three agents. This treatment resembles a 'perfect commitment' equilibrium, with exploitation power for the first player and no exploitation power for the second and third player. The condition relates to the discussion on ecological dictatorship (Stehr 2015); because there is no coordination problem, the dictator has the possibility to implement a benevolent dictatorship with full resource conservation and maximum social welfare. However, selfish motives may lead the dictator to forgo social welfare maximization. The treatment thus informs in how much cooperation failure versus selfish preferences can account for failure to achieve the socially optimal level of conservation.

The *Rawls* treatment requires agents to propose a decision for all three positions in the game, not yet knowing which position they will hold. The proposal that is implemented and the positions in the game are determined randomly after the decisions are made. Thus, the Rawls treatment reflects the 'veil of ignorance:' the players do not know in advance their role in the game, and their expected payoff is maximized by maximizing the group payoff (full conservation). This condition therefore should shift the agents' focus towards social welfare maximization.

Predictions

On the basis of the different policy and ethical conditions for the cooperation dilemma we can summarize the theoretical predictions. Table 1 shows the expected equilibrium payoffs for each player ex-ante, before player roles are allocated, as well as overall expected equilibrium payoff $\mathbb{E}(V_i)$. The table also shows the equilibrium resource conservation S_4. Certainty and Rawls provide highest expected payoffs, followed by Dictator, Solar and Liberal. Note that equilibrium payoffs differ in their distributional riskiness (variation of payoffs over generations), and also in terms of their strategic uncertainty, caused by the possibility of non-equilibrium play of later players. Importantly, we observe that the risky conditions Solar and Dictator provide insurance against exploitation by later players.

Our benchmark prediction is risk-neutral equilibrium play in each condition. When institutional choice becomes relevant in the voting stage, we predict that Certainty and Rawls will be selected. Behavioral patterns may deviate from the current predictions for various reasons. Riskiness of the different conditions may affect behavior, as well as beliefs about other players. More subtle may be the effects of the degree of control. In Liberal and Certainty, all subjects' decisions are part of the outcome. In the other three conditions players may be exposed to decisions explicitly imposed on them. A central question in the current paper is how people perceive the value and the legitimacy of the different conditions, which is especially relevant from a practical viewpoint with respect to the policy interventions, and how these aspects may affect realized outcomes in each condition.

TABLE 1. Predictions of expected payoffs in equilibrium

Condition	Equilibrium	$\mathbb{E}(V_1)$	$\mathbb{E}(V_2)$	$\mathbb{E}(V_3)$	$\mathbb{E}(V_i)$	S_4
Liberal	Exploit if given the opportunity	6	6	0	4	0
Certainty	Never exploit	8	8	8	8	2
Solar	Player 1 exploits and invests; Players 2 and 3 cannot exploit	9	4	4	5.67	1
Dictator	Player 1 exploits and forces Players 2 and 3 to conserve	10	4	4	6	1
Rawls	Players 1, 2, and 3 do not exploit	8	8	8	8	2

Empirical Methods

Our computerized experiment (zTree; Fischbacher 2007) involved 120 student participants from Tilburg University. The games were translated into Euro values by a 1-for-1 mapping of equation 2 (resp. equation 9). Participants played multiple games, one of which was randomly selected at the end of the experiment for monetary payments according to participants' actual choices in this game.

The experiment consisted of three stages. In the first stage, groups of three players played each of the five games exactly once (i.e., no repetition). Participants did not know the identity of their group members, and no feedback on choices and payoffs was given between the games. Importantly, each participant made decisions for all three positions in the game, for positions 2 and 3 these were conditional on the different stocks of the resource that were potentially left when the agent had to make his choice. Thus, when making decisions, subjects did not know the exact amount of resources that were taken from the common pool, as in Budescu et al. (1995). In condition Rawls this elicitation of full strategies was necessary to implement payoffs (because one person's decisions determine the full vector of choices). In the other conditions, the procedure allows us to observe strategies also for events that rarely obtain in sequential play (e.g., Brandts and Charness 2011), and maintains comparability of structure to the Rawls condition. For each game, after all strategies had been submitted, the position of the three players was randomly determined and choices were implemented according to the rules of the specific condition (but no feedback was given until the end of the experiment). To control for order effects when making choices in the 5 games, each group was assigned one of 40 pre-selected orders (out of the 120 possible orders) of the 5 games. We pre-selected these orders such that each game was played equally often in each position while also being played equally often earlier or later than any other game in pair-wise comparison.

The second stage measures participants' preferences over the different institutions. Players were asked to vote for the game that they would prefer to repeat once more. We used a simple majority rule to determine for each group of 3 players which game was played again. In the case of a tie, each of the three treatments that received a vote had a chance of 1/3 to be selected. While subjects were informed about the result of the vote as well as the implemented random order of positions, they were not informed about individual votes or actions other than their own.

The third stage matched participants in new groups of three players. Then each of the groups was randomly assigned to one of the five conditions, such that each condition was played by the same number of groups over the course of the experiment. These groups then played the selected condition 6 times repeatedly with feedback after each round. That is, at the end of each round, players were informed about their role, remaining resource units at their position and the consequential decision, as well as the final resource conservation and the resulting payoffs. Individual actions by other were not identifiable by the participants. This allowed the participants to learn about the behavior of others (which was impossible in stages 1 and 2), and to adjust their behavior accordingly, without providing the opportunity to react to specific actions by other individuals. When discussing stage 3 results, we always report results from the last iteration of the game in stage 3, that is, for behavior of experienced players.

After stage 3 of the experiment, participants filled in a questionnaire that elicited individual characteristics such as attitudes towards risk (using an incentivized elicitation tasks), political orientation, views on climate change, numeracy, gender, age, study, and year of study. More details on the experimental implementation, as well as instructions and screen content, can be found in the appendix.

Results

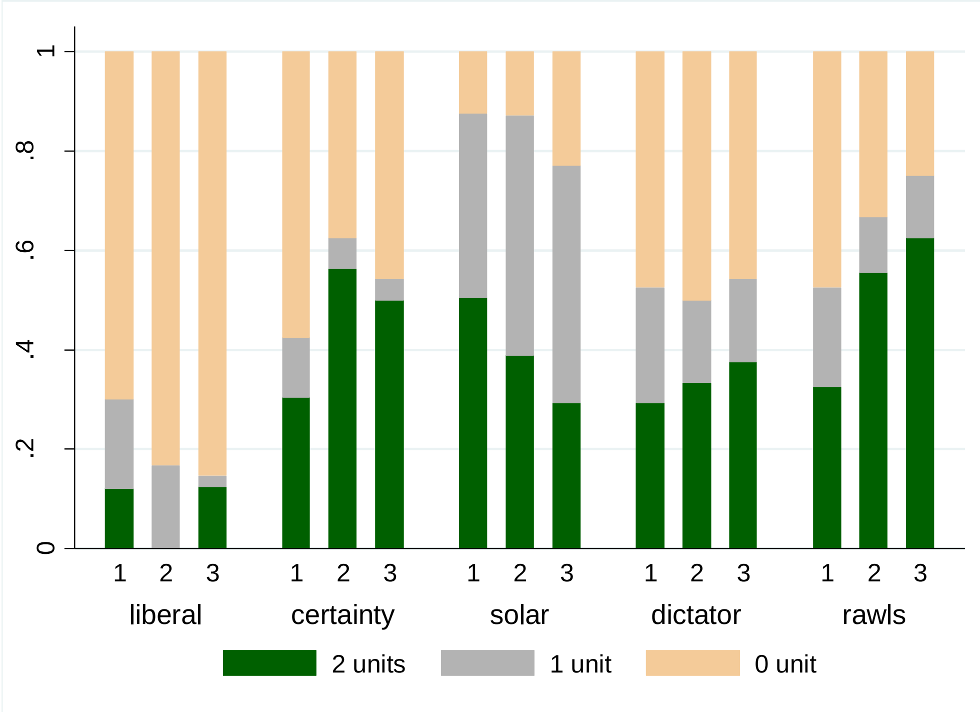
We first discuss results at the group level. In the following subsections we analyze the individual strategies in stages 1 and 3 and stage 2 voting behavior.

Outcomes at group level

Figure 1 summarizes resource conservation (0, 1, or 2 units) in the five different conditions. For each condition we show average results in stage 1 (one-shot interaction), stage 2 (self-selected conditions after voting), and stage 3 (after six repetitions with feedback). In the calculation of conservation outcomes the figure accounts for within-group interaction by averaging game outcomes over all possible permutation of allocations of generational positions (and accompanying decisions). Results for the Liberal condition demonstrate the essence of the resource extraction dilemma, with only very low levels of resource conservation in all three stages. That is, our results confirm the relevance of coordination problems in the intertemporal setting, allowing for sensible assessments of the effects of the different policy interventions and the ethical conditions.

Compared to the Liberal condition, the other conditions increase conservation. However, in contrast to the predictions in Table1, Certainty and Rawls do not outperform Dictator and Solar in the initial round (stage 1); only after sufficient experience do these conditions lead to higher conservation. Clearly, even in the last round of stage 3 is the average conservation over groups substantially lower than the predicted full conservation. Interestingly, while Certainty and Rawls lead to predominantly full or zero conservation, Solar and Dictator shows more prevalence of exactly one resource unit conserved. This finding is consistent with equilibrium predictions. The dynamics of behavior differ across conditions. The effect of Solar seems to be immediate and becomes more moderate with repetition; the effect of Certainty and Rawls requires some experience to emerge fully. Table 2 provides more details and statistical test of these observations.

FIGURE 1. Resource conservation dependence on conditions and stages



Note: The chart shows the frequency for conservation outcomes (0 unit, 1 unit, or 2 units) over all games in a condition. Within each condition, the first column presents the results for stage 1, the second column shows results for stage 2 (after voting), and the third column shows results for stage 3 (last iteration).

Table 2 shows conservation rates in stages 1 (columns 1-3) and 3 (columns 4-6), and the social welfare effects of the different conditions (columns 7 and 8), as a percentage of the maximum potential outcome. The table provides two perspectives on conservation outcomes. The first perspective measures the differences across conditions in terms of individuals' conservation strategies (columns 1 and 4). The second perspective measures the differences across conditions in terms of each groups' expected conservation success (columns 2 and 5). More precisely, the variable $\bar{S}_4^O$ is defined as the resource stock left at the end of the game averaged over all players in the fictitious condition when for each player the own strategy would be implemented for all 3 player roles. As this variable does not involve any group effects,[1] we consider this variable a measure for the individual resource conservation strategy. The variable $\mathbb{E}(S_4)$ gives the expected resource stock left at the end of the game on a group level as in Figure 1, averaging over all possible random selections of subjects in each role. For the Dictator and Rawls condition both perspectives yield the same results as these conditions always implement the strategy of one player by design. For the Liberal, Certainty and Solar condition, the gap

[1] Apart from potential learning effects in stage 3 that indirectly affect individual behavior.

between the two variables measures the costs of incoherent strategies between the group members. That is, although a significant number of players may aim to conserve resources, groups in these conditions may still perform poorly due to a few agents who exhaust the resource when given the opportunity.

TABLE 2. Resource conservation and expected social welfare

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	$\bar{S}_4^O$	$\mathbb{E}(S_4)$	(1)–(2)	$\bar{S}_4^O$	$\mathbb{E}(S_4)$	(4)–(5)	$\mathbb{E}(V)$	$\mathbb{E}(V)$
Player-interaction	*No*	*Yes*		*No*	*Yes*		*Yes*	*Yes*
Stage	1	1	1	3	3	3	1	3
Liberal	41	21	20***	17	14	3	21	14
Certainty	51**	36***	15***	63**	52##	10	24	48
Solar	75***	69***	6***	54**	53**	1	57***	41**
Dictator	41	41***		46**	46**		41***	46**
Rawls	43	43***		69**	69***		43***	69***

Notes: Resource conservation and expected social welfare expressed in percentage of potential maximum, on the scale from 0 to 100. Outcomes/payoffs are expected values over all subjects and positions. Columns 1+4 present (fictitious) outcomes if players played against themselves. Columns 2+5 present expected group outcomes and columns 3+6 present the effect of these within-group interactions between players. Columns 7+8 present expected group payoffs. *,**,*** indicates significance at the 10%, 5%, 1% level. For columns 1+2+7, significance is determined by comparison with the Liberal treatment, using Wilcoxon matched pairs test. For columns 3+6, significance is based on comparison with zero, using Wilcoxon matched pairs test. For column 4+5+8, significance is based on comparison with the liberal treatment, using the Mann-Whitney two-sample tests. ## indicates that the certainty treatment has a p=0.05 significance higher probability of full resource conservation than Liberal, though the MW test does not provide significance for the full resource conservation vector.

Based on Table 2, we can make a few observations regarding average performance of the different institutions. Both policy interventions (Solar and Certainty) perform better in terms of resource conservation than Liberal, irrespective of whether we consider the individual strategies or the average group outcomes. This is true for unexperienced behavior in stage 1 (columns 1 and 2), as well as for experienced behavior in stage 3 (columns 4 and 5). For experienced interactions there is little difference between the two policy conditions. In the absence of experience and at the group level (arguable the most relevant conditions from a practical perspective), the Solar condition outperforms Certainty (69% vs. 36%, $p<0.01$, Wilcoxon test). That is, although full resource conservation is the unique Nash Equilibrium for Certainty, empirically participants seem to hold pessimistic beliefs about other decision makers' actions and often fail to coordinate. Interestingly, the 'exhaustible resource curse' with the most exploitive player dominating the group outcomes is only relevant for unexperienced players (column 3). No significant differences are detected for stage-3 behavior (column 6). Players learn the other group members' strategies and adapt their own strategy accordingly. Interestingly, the effect of the adaptation points into different directions in the two policy treatments. For Certainty, individual and group outcomes increase insignificantly (51% vs. 63%, n.s., Wilcoxon matched pairs test; 36% vs. 52%, n.s., Mann-Whitney U test); in contrast, in Solar there is a downward trend in conservation with experience (75% vs. 54%, p<0.01 Wilcoxon matched pairs; 69% vs. 53%, n.s., Mann-Whitney U test). In the Liberal condition, the individual strategies become also more exploitive: conservation in stage 3 is significantly lower than in first stage (17% vs. 41%, p=0.01, Wilcoxon matched pairs test). Group outcomes do not change with experience, mainly because they were very low already (14% vs. 21%, n.s, Mann-Whitney U test).

The two ethics conditions show a somewhat different pattern. These conditions perform better than Liberal in stage 1 only in terms of group outcomes, but not in terms of individual strategies. However, with sufficient experience in stage 3 both conditions clearly outperform conservation in Liberal. This is due to two sources. On the one hand, performance in the ethics conditions shows an upward trend with experience (41% vs. 46%, n.s.; 43% vs. 69%, p=0.03, Wilcoxon matched pairs test). Some experience seems necessary to understand the mechanics of the social allocation mechanisms. On the other hand, the performance of Liberal further deteriorates with experience. Interestingly, the Dictator condition shows that even if coordination failure can be overcome, selfish preferences still preclude more substantial conservation outcomes.

We can finally look at the social welfare implications of the different conditions (columns 7 and 8). Without any experience, policy intervention Solar and the two ethics conditions outperform Liberal in terms of welfare (i.e., accounting for investment costs). Although Certainty outperforms Liberal in terms of conservation (column 2), the less favorable mapping from conservation to climate catastrophe makes the two conditions indistinguishable in terms of welfare. Remarkably, Solar outperforms Liberal despite the additional costs involved, in line with the theoretical equilibrium predictions. After participants have been able to gather some experience with the different mechanisms, the same picture emerges. Although Certainty induces a level of welfare comparable to that of Solar, its effect is not statistically significant due to higher variability (Figure 1). Finally, we can put the performance of Certainty, Solar, and Dictator conditions in perspective by comparing it to the maximum social welfare that was empirically achieved in the Rawlsian condition, where social welfare maximization should be easiest to attain. Clearly, with sufficient experience players do attain the highest level of welfare under Rawls. That is, selfish motives and cooperation problems constrain resource conservation in the other conditions. However, accounting for the fact that only 69% of the theoretical maximum is achieved for Rawls shows that solar and certainty can bridge about half of the gap between the low Liberal outcome and the best possible Rawls outcome.

Individual strategies

We analyze individual behavior in the intertemporal cooperation setting with respect to two questions. First, do people condition their behavior on other people's decisions? Second, do they behave differently depending on the position in the game (conditional on identical resource endowment)? Table 3 shows individual resource extraction strategies, for each position in the game and dependent on resources conserved by previous players. Note that for conditions Dictator and Rawls there were no such conditional strategies as the full strategy of one selected player was implemented for the group.

Table 3 shows a tendency for conditionality in Liberal, Certainty and Solar. Entries in columns 3 and 5 are always larger than the corresponding entries in columns 2 and 4, although not all comparisons are significant. That is, if previously the resource has been exploited by at least one person, people are more likely to also exploit the resource. Note that in Certainty, this behavior should follow directly from the fact that conservation is not beneficial once the first unit has been exploited. Comparisons of columns 2 and 4 to column 1 show that people are typically less likely to exploit the resource the later in the game they are called to make a decision, conditional on full resource conversation S_i=2 at the moment of their decision.[2] That suggests that pessimistic beliefs about later players' behavior negatively affects people conservation decisions. Beliefs thus seem to play an important role in the breakdown of cooperation.

[2] Note that the effect is less pronounced in Solar. In Solar, decisions for generation 2 and 3 may not become relevant if generation 1 player restricts choices by investing in the solar technology. Conditionality in choice may thus be diluted by (i) the potential irrelevance of the decision (unknown at the moment the decision is made), and (ii) strategic considerations regarding the question why generation 1 did not restrict (which is the case when the decision becomes relevant).

TABLE 3. Individual Exploitation Strategies R_i

Variable Conservation level	(1) $\mathbb{E}(R_1)$	(2) $\mathbb{E}(R_2)$ S_1=2	(3) $\mathbb{E}(R_2)$ S_1=1	(4) $\mathbb{E}(R_3)$ S_2=2	(5) $\mathbb{E}(R_3)$ S_2=1
Stage 1					
Liberal	0.63	0.54	0.63	0.38 ***	0.64 ***
Certainty	0.49	0.35**	0.73 ***	0.15 ***	0.72 ***
Solar	0.41	0.51	0.59	0.35	0.58 ***
Stage 2 (voting)					
Liberal	0.67	0.67	0.78	0.39 *	0.78 **
Certainty	0.33	0.17 **	0.71 **	0.00 **	0.79 ***
Solar	0.57	0.52	0.70	0.37 **	0.70 **
Stage 3 (experienced, i.e., in last repetition)					
Liberal	0.88	0.58 **	0.83	0.38 **	0.88 **
Certainty	0.38	0.38	0.79 **	0.17 *	0.75 **
Solar	0.67	0.63	0.88 **	0.54	0.79

Notes: Entries are expected resource extraction averaged over participants in a condition. Stage 1 comparisons based on one-sample tests of proportion on individual level. Stage 2 and 3 based on Wilcoxon matched-pair tests on group level. In columns 2 and 4, *,**,*** indicates significant differences at the 10%, 5%, 1% level, compared to column 1; in columns 3 and 5, *,**,*** indicates significant differences at the 10%, 5%, 1% level, compared to columns 2 and 4, respectively.

Voting and voting effects

Stage 2 of the experiment offers insights into participant's preferences among the different conditions. Table 4 shows that preferences vary widely. While Solar is the modal vote, its majority is modest with just 37% of the votes. The preference for the other four conditions is virtually identical, despite these conditions offering vastly different opportunities for cooperation and payoffs. Note that all players experienced each of the five conditions exactly once in Stage 1 without any feedback on the behavior of others. Thus, preferences between conditions cannot derive from random experiences due to behavior of the other players in the group. Clearly, people have obtained only a modest degree of intuition about the potential payoffs of the different conditions from the one-shot decision made in each condition.

However, the middle panel of Table 3 shows that there are pronounced differences among conditions in Stage 2 after voting, i.e., conditional on playing the game that has been elected in a group. Thus, although not all players in a group may play the game they have in fact voted for, this suggest that voting (and playing) was not random and that players took the special features of each condition into account once they reached stage 2. We therefore analyze the potential predictors of voting behavior in terms of participants' Stage 1 behavior in more detail. Results are shown in Table 4.

TABLE 4. Stage 2 Voting and Stage 1 Individual Strategies Conditional on Voting

Voted for	(1) Liberal	(2) Certainty	(3) Solar	(4) Dictator	(5) Rawls
Observations / %	22 / 18%	23 / 19%	44/37%***	12/10%***	19 / 16%
Stage 1 behavior	*Resource conservation $\bar{S}_4^O$ (percentage out of 2)*[a]				
Liberal	39	41	45	21	45
Certainty	45	70**	48	33	55
Solar	75	85*	77	67	66*
Dictator	48	39	35	29	55*
Rawls	36	59*	34	33	55
Average	39	51**	41	31**	44
% Invested in technology in Solar	68	47***	92***	75	60

Note: The table reads as follows: The 22 players who voted Liberal are collected in the first column, etc. The first row collects all outcomes of the liberal treatment. Significance in first row indicates difference from 20%. In other rows, significance indicates that those subjects voting for the specified treatment had significantly different scores for the variable, compared to all players who voted for another treatment. *,**,*** indicates significance at the 10%, 5%, 1% level.

Table 4 shows resource conservation as predicted on the basis of individual behavior only (no interaction; $\bar{S}_4^O$). In each column, data on those participants who voted for the respective condition, and in each row, Stage 1 results for these participants in each of the five conditions are shown. It also shows average behavior and choice of the investment option in the Solar condition. We first observe that people do not vote for the condition that performed best conditional on their own behavior, except for the Solar voters. In fact, Solar performed best for all groups, but those who take up the commitment device mostly also vote for it. Certainty voters tend to conserve more resources than other participants for 3 specific conditions and overall, but invested the least in Solar as a commitment device. Potentially these players believe that Certainty offers a cheaper condition for coordination and appreciate less the costly Solar commitment device. At the other extreme, we find that Dictator voters conserve the least compared to other players. Rawls voters have the higher conservation in the Dictator condition than other voters, suggesting other-regarding preferences play a larger role for these players. The poor performance and voting outcome of Rawls confirms the above-discussed result that significant experience is necessary to understand how the Rawls mechanism allows groups to align individual and group preferences. Investment in the renewable technology in Solar differs vastly across voters. Clearly, the modest voting success of Solar despite its good performance can be explained by low take up of the investment opportunity for non-Solar voters. We note that there were no significant correlations of voting behavior with individual differences in the subject's risk aversion, gender, or concerns for global warming.

Discussion

We study the intertemporal resource extraction problem that is inherent to climate change mitigation in an experimental setting. We find that with scientific uncertainty about dangerous thresholds, and in the absence of commitment devices, participants do not succeed in coordinating actions to prevent climate catastrophe. There is clear evidence of an 'exhaustible resource curse': conservation choices are substitutes over time. Our game specification is simple and only offers discrete choices to subjects; yet we believe that this feature of our game is robust. It has been observed in other games with semi-continuous choices (Barret and Dannenberg 2012), and studies repeatedly report that fossil fuels will continue their dominance in absence of drastic global policies (Covert et al. 2016).

We introduce two different mechanisms to mitigate the coordination problem. First, a reduction of uncertainty significantly improves resource conservation, despite being strictly worse in terms of the climate effects of conservation. This effect confirms earlier findings in the horizontal cooperation problem (Barret and Dannenberg 2012). Second, a costly commitment device significantly improves resource conservation and social welfare, despite being purely wasteful investment. These results constitute an important insight. We find that participants are willing to pay upfront costs to reduce resource exploitation in later rounds. Moreover, we find that this mechanism receives most support from the subjects, even if they do not know ex ante whether they will operate, or be constrained by the commitment device (i.e., their position in the game). This suggests that high investment costs in technology and infrastructure for renewable energy should be assessed also from the perspective of their benefits for intertemporal coordination. While present decision makers cannot commit future carbon prices, they can invest in clean energy and commit to a future stream of non-carbon energy supply. The result does not suggest that standard economic reasoning is invalid: a global agreement that sets explicit or implicit sufficiently high carbon prices remains the most efficient instrument available to reduce greenhouse gas emissions. While waiting for such an agreement, costly investments in clean energy could be an essential step. Importantly, the instrument seems to be perceived as legitimate by those who are exposed to it.

We also study the ethical aspects of the cooperation problem in two conditions: an ecological dictatorship that depends on the social preferences of the dictator and a Rawlsian approach that should in principle implement maximum conservation. Both conditions outperform the Liberal unregulated condition. Dictator is equally successful in the long-run as the two policy conditions, and Rawls is, unsurprisingly, more successful. Importantly, even with repeated experience, participants fail to implement full resource conservation in all conditions. As the Dictator condition shows, even if coordination failure can be overcome, low weight on other players' welfare is still a constraint on socially optimal resource conservation. Moreover, as shown in the analysis of conditionality, pessimistic beliefs about people making decisions at a later stage prevent higher degree of conservation.

Combining the insights from the Dictator condition and the Solar condition, we note that strategic instruments that aim at distorting future decisions also carry a danger (Goeschl et al. 2013). From an ethical perspective, it is desirable that current decisions improve the future choice set, and do not restrict these for the benefit of the present. Clean energy investments seem to satisfy this criterion.

Literature.

Barrett, S. (1994), Self-enforcing international environmental agreements, Oxford Economic Papers 46: 878-894.

Barret, S. and A. Dannenberg (2012), Climate negotiations under scientific uncertainty, PNAS 109: 17372-17376.

Brandts, J. and G. Charness (2011), The strategy versus the direct-response method: a first survey of experimental comparisons, Experimental Economics 14: 375-398

Budescu, D., A. Rapoport and R. Suleiman (1992), Simultaneous vs. Sequential Requests in Resource Dilemmas with Incomplete Information, Acta Psychologica 80: 297-310.

Budescu, D., R. Suleiman and A. Rapoport, A. (1995), Positional order and group size effects in resource dilemmas with uncertain resources, Organizational Behavior and Human Decision Processes 61: 225-238.

Chichilnisky G (1996) An axiomatic approach to sustainable development. Social Choice and Welfare 13: 231–257.

Covert T. M. Greenstone, C.R. Knittel (2016), Will we ever stop using fossil fuels?, Journal of Economic Perspectives 30: 117-138.

Erev, I., & Rapoport, A. (1990), Provision of step-level public goods: the sequential contribution mechanism, Journal of Conflict Resolution 34: 401-425.

Fischbacher, U. (2007), Z-Tree: Zurich toolbox for ready-made economic experiments, Experimental Economics 10: 171–178.

Gerlagh, R. (2011), Too much oil. CESifo Economic Studies 57(1): 79-102.

Gerlagh, R., and T. Michielsen (2015), Moving targets – cost-effective climate policy under scientific uncertainty, Climatic Change 132: 519-529.

Goeschl T., D. Heyen, J. Moreno-Cruz (2013), The Intergenerational Transfer of Solar Radiation Management Capabilities and Atmospheric Carbon Stocks, Environmental and Resource Economics 56: 85-104.

Harstad, B. (2015), Investment policy for time-inconsistent discounters, working paper.

Hauser O.P., D.G. Rand, A. Peysakhovich, M.A. Nowak (2014), Cooperating with the future, Nature 511: 220-223.

Holtsmark, K. and K. Midttomme (2015), The dynamics of linking permit markets, working paper.

Karp, L. (forthcoming), Provision of a public good with multiple dynasties, Economic Journal, forthcoming.

Michielsen, T. (2014), Brown backstops versus the green paradox, J. of Environmental Economics and Management 68: 87-110

Neubersch, D, H. Held, and A. Otto (2014), Operationalizing climate targets under learning: an application of cost-risk analysis, Climatic Change 126: 315–328

Peters, E., D. Vastfjall, P. Slovic, C. K. Mertz, K. Mazzocco, and S. Dickert (2006), Numeracy and Decision Making, Psychological Science 17: 407-413.

Schmidt, M.G.W., A. Lorenz, H. Held, E. Kriegler (2011), Climate targets under uncertainty: challenges and remedies, Climatic Change 104: 783–791

Sinn, H.W. (2008), Public policies against global warming, International Tax and Public Finance 15: 360-394.

Stehr, N. (2015), Democracy is not an inconvenience, Nature 525: 449-450.

Sutter, M., Haigner, S., and M.G. Kocher (2010), Choosing the carrot or the stick? Endogenous institutional choice in social dilemma situations, The Review of Economic Studies 77: 1540-1566.

Thaler, R. and E. Johnson (1990), Gambling with the house money and trying to break even: the effect of prior outcomes on risky choice, Management Science 36: 643-660.

Online support material

Appendix A: Details on the Experimental Method

General Procedures

The experiment was conducted at Tilburg University with 120 student participants. Students were recruited via an online recruiting system. The experiment was programmed in zTree (Fischbacher 2007). The experiment consisted of 3 stages with a total of 12 tasks: Stage 1 consisting of tasks 1-5; Stage 2 consisting of task 6; and Stage 3 consisting of tasks 7-12. A final task 13 consisted of a risk attitude assessment and was followed by a questionnaire to collect background information on the participants' demographics (see "Controls"). At the start of the experiment, subjects were randomly allocated to private computers and to groups of 3 participants. At the beginning of each stage, general instructions were handed out on paper and read out aloud by the experimenter. Additionally, task-specific instructions were presented on the computer screen (see Appendix B). The instructions employed a neutral frame and language; meaningful labels were removed to avoid potential confounding effects due to use of language. Any questions were answered in private. Task 1-12 concerned 5 types of games that participants played in groups of 3 (see "The Games").

The Games

In the *Liberal* game, each group started with a common pool of €12. Subjects were informed that group members would randomly be assigned a player role (Player 1, Player 2, or Player 3), and that each group member would have the option to take €6 from the common pool sequentially, in order of the player number. Every €6 taken from the common pool was rewarded privately. Subjects were informed that if there was €12 (€0) remaining in pool at the end of the game (i.e., after the action of Player 3 was implemented), each group member would receive €8 (€0) privately. If there was €6 remaining in the common pool, there was a 50% chance that each group member would receive €8 extra, and a 50% chance that each group member would receive nothing extra.

The *Certainty* game was similar to the *Liberal* game, except for the fact that there was no uncertainty about the amount that subjects would receive at the end of the game if there was €6 remaining in the common pool; each group member would receive €0 in that case. The *Solar* game was similar to the *Liberal* game, except for the fact that in the role of Player 1, subjects could decide to remove the possibility of the other group members to take €6 from the common pool, at the cost of €1. The *Dictator* game was similar to the *Liberal* game, except for the fact that all actions of the group member assigned the role of Player 1 were implemented. Thus, in the Dictator game, the actions by Player 2 and Player 3 were in fact determined by the group member assigned the role of Player 1. The *Rawls* game was similar to the *Liberal* game, except for the fact that all the actions of a randomly chosen group member were implemented. That is, players were randomly assigned the position in the game, and then one person's strategy vector was implemented. For example, in case the actions of Player 2 were chosen to be implemented, the action by Player 1 and Player 3 were determined by the actions of the group member assigned the role of Player 2 in the Rawls game.

Specific Procedures

In the first five tasks, subjects simply played each of the five games once without receiving feedback. To measure individual preferences towards each game, subjects were asked to vote for the game that they would prefer to repeat once more with majority voting at the beginning of task 6. The game that was thus selected was played once more in task 6. In case of a voting tie, each of the three games that received a vote had an equal 1/3 chance of being implemented in task 6. After task 6, the groups were reshuffled such that all subjects were in a different group, i.e., each subject was

assigned to a new group with 2 participants that were not in their group before. These groups then played one of the five games
repeatedly with feedback six times in task 7-12 within the same group. Thus, at the end of each game, subjects were informed about their player role, the action chosen by them, the actions chosen by the other group members, and their resulting payoff in that task.

Controls

To control for potential order effects, the order of the games in task 1-5 was fixed beforehand such that each of the 120 possible orders of games was represented exactly once, i.e., each participant played the five games in a different order. To control for individual attitudes towards risk, the final task concerned the elicitation of a certain monetary amount that made subjects indifferent between receiving the certain amount and between receiving a lottery yielding either €10 or nothing with equal (50/50) probability, depending on the outcome of a die roll performed at the end of the experiment. In particular, respondents were asked to make a series of 21 choices between the lottery and an ascending range of certain amounts grouped together in a list. The certain amounts in the list ranged from €0 in the first choice to €10 in the final choice, and increased in equal steps of €0.50. The midpoint of the last choice in which the subject chose the lottery and the first choice in which the subject chose the certain amount was taken as the certain amount that made the subject indifferent. A certain amount lower/higher than the expected value of the lottery (€5) is indicative of risk averse (seeking) preferences.

In task 13, subjects were asked to report gender, age, study year, and type of study. In addition, we measured political orientation (left, middle, right), and attitudes towards global warming. Finally, we obtained an individual measurement of numeracy using 5 items from the numeracy scale employed by Peters et al. (2006; items 1, 2, 3, 7, and 10).

Payment

To avoid potential income effects (such as Thaler and Johnson’s (1990) house money effect), 1 of the 13 tasks was randomly selected by to be paid for real. For this purpose, at the start of the experiment, one participant was asked to assist the experimenter in drawing one envelope from a pile of sealed envelopes, each containing a card numbered 1-13. Participants were informed that the envelope would be opened at the end of the experiment and that the task corresponding with the number on the card inside the envelope would determine the earnings of the experiment. Additionally to the task-contingent earnings, all subjects received a fixed show-up fee of €4. On average, subjects earned €9.32, while the experiment took about 1 hour and 15 minutes to complete.

Appendix B: Experimental Instructions

General Instructions
Welcome to this experiment. During the experiment:

- please no talking
- turn off your cell phone
- and raise your hand if anything is unclear, to be helped in private

This experiment consists of 13 tasks in total. Some tasks will involve a game that you will play with other participants; other tasks will involve choices between lotteries. For now, it is important to know that 1 of the 13 tasks will be randomly selected to be paid for real at the end of the experiment. For this purpose, the experimenter will now ask one of you to select an envelope from a pile of sealed envelopes containing cards with numbers 1-13 on them. In particular, the experimenter will ask one of you to draw an envelope from the pile of envelopes at random and sign it, so that you know that the envelope that will be opened at the end of the experiment indeed was the envelope selected by one of you.

<Experimenter will now ask one participant to draw an envelope>

Thus, at the end of the experiment, the randomly selected envelope will be opened, the numbered card will be shown to you, and your earnings in the task that corresponds with the number on the card will be paid for real. Suppose for example that the number on the card is 9. Then, you will be paid your earnings in the 9th task. On top of these earnings, you will receive a show-up fee of €4. Thus, your total earnings in the experiment are determined as follows:

Total earnings = Earnings of 1 of the 13 tasks (randomly selected) + show-up fee of €4.

All earnings will be paid to you in private. Your earnings in this experiment will be transferred to your bank account. The experimenter will now hand out the instructions for the first 5 tasks and read these instructions aloud. When everybody has completed the first 5 tasks, additional instructions will be handed out. Good luck!

Instructions Task 1-5
The first 5 tasks concern a game that you will play with two other participants. For this purpose, the computer will randomly match you with 2 other participants of this experiment for the duration of the first 5 tasks. You will not learn the identity of your group members; neither will your group members learn your identity. Each group has 3 members.

The 5 games that you and your group members will play all involve 3 player roles: Player 1, Player 2, and Player 3. The computer will randomly assign a role to you and to your fellow group members after you made your decisions. Thus, you do not know yet what your role will be when you are asked to make a decision. Hence, each group member is asked to make a decision for the three possible cases; that (s)he is selected as Player 1, Player 2, or Player 3. Notice that it is equally likely that you will be assigned the role of Player 1, Player 2 or Player 3 (i.e. the chance for each role is equal to 1/3).

Each game is played as follows: The group starts with a common pool of €12. In each role you can take out exactly €6 from the common pool, as long as there is money in the pool. Hence, each member decides whether or not to take €6 from the common pool for the three cases of being selected as Player 1, Player 2, or Player 3. The choices will be implemented sequentially, that is, Player 1 decides first whether to take €6 from the common pool, followed by Player 2, and finally by Player 3. Therefore, the decisions made by Player 2 and Player 3 are conditional on the amount of euros remaining in the pool after the previous players have made their decisions. For example, in the role of Player 2, you will be asked separately whether you want to take €6 from the pool if there are €6 remaining, and whether you want to take €6 if there are €12 remaining in the common pool. Which of the two cases holds depends on the choice of Player 1.

In each game, each player who takes €6 from the common pool receives these €6 privately. After all 3 players made their decision, the computer checks how much euros are left in the common pool at the end: 0, 6 or 12. Then, each player receives an amount of euros on top of the private earnings depending on how many euros are left in the common pool as follows:

- If there are €0 left in the common pool, each player receives nothing.
- If there are €12 left in the common pool, each player receives €8.
- If there are €6 left in the common pool, then what happens depends on the game; game specific details will be given on your decision screen.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, the experimenter will soon start the program for the first 5 tasks.

Instructions Task 6

In this task, you and your fellow group members will decide which of the first 5 tasks will be repeated once more. Thus, task 6 will be a repetition of either task 1, task 2, task 3, task 4 or task 5. To select the task that is going to be repeated once more, each group member will be asked to cast a vote on the task that (s)he prefers. The task that has the majority of the votes will be the one that will be repeated once more. If all group members vote for a different task – i.e., if each task receives 1 vote – the task will be selected at random from those that have received a vote. For example, if group member 1 votes to repeat task 2, group member 2 votes to repeat task 5 and group member 3 votes to repeat task 1, the computer will select either task 2, task 5 or task 1 with equal (1/3) chance.

In each task, you were asked to indicate whether you wanted to take €6 from the pool in case you are selected as Player 1, Player 2, and Player 3, conditional on how many euros were remaining in the common pool. Each player who took €6 from the common pool received these €6 privately. If after all three players made their decisions there were €0 remaining in the common pool, then there would be no payment to the players additional to their payments based on the private decisions. If there were €12 remaining in the common pool, then each player received an additional €8.

On your screen, you will find a summary of the task-specific instructions, so you can make a well-informed vote. Please raise your hand if you need further explanation from the experimenter. If you have no questions, the experimenter will soon start the program.

Instructions Task 7-12

The next 6 tasks again concern a game that you will play with two other participants. For this purpose, the computer will again randomly match you with 2 other participants of this experiment for the duration of the 6 tasks. Importantly, you will be matched with 2 **other** participants; your group members will not be same ones you were matched with in the first 6 tasks of today's experiment. Again, you will not learn the identity of your group members; neither will your group members learn your identity, and each group has 3 members.

Again, the 6 games that you and your group members will play all involve 3 player roles: Player 1, Player 2, and Player 3. The computer will randomly assign a role to you and to your fellow group members after you made your decisions. Thus, you do not know yet what your role will be when you are asked to make a decision. Hence, each group member is asked to make a decision for the three possible cases; that (s)he is selected as Player 1, Player 2, or Player 3. Notice that it is equally likely that you will be assigned the role of Player 1, Player 2 or Player 3 (i.e. the chance for each role is equal to 1/3).

Each game is again played as follows: The group starts with a common pool of €12. In each role you can take out exactly €6 from the common pool, as long as there is money in the pool. Hence, each member decides whether or not to take €6 from the common pool for the three cases of being selected as Player 1, Player 2, or Player 3. The choices will be implemented sequentially, that is, Player 1 decides first whether to take €6 from the common pool, followed by Player 2, and finally by Player 3. Therefore, the decisions made by Player 2 and Player 3 are conditional on the amount of euros remaining in the pool after the previous players have made their decisions. For example, in the role of Player 2, you will be asked separately whether you want to take €6 from the pool if there are €6 remaining, and whether you want to take €6 if there are €12 remaining in the common pool. Which of the two cases holds depends on the choice of Player 1.

In each game, each player who takes €6 from the common pool receives these €6 privately. After all 3 players made their decision, the computer checks how much euros are left in the common pool: 0, 6 or 12. Then, each player receives an amount of euros on top of the private earnings depending on how many euros are left in the common pool as follows:

- If there are €0 left in the common pool, each player receives nothing.
- If there are €12 left in the common pool, then each player receives €8.
- If there are €6 left in the common pool, then what happens will be described on the left side of the screen.

In the next 6 tasks, you will play the same game with the same group members and you will directly receive feedback about the outcome of the game after each group member has made their decision. Thus, you know your payoffs in each task.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, the experimenter will soon start the program for the next 6 tasks.

Instructions Task 13

The final task concerns several choices between two options, labelled LEFT and RIGHT, grouped together in a list. Both options will yield an amount of money, potentially depending on the throw of a standard six-sided die performed at the end of the experiment. If this task is selected to be paid for real, you payoff will depend on the option you have chosen and, potentially, on the throw of the six-sided die.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, the experimenter will soon start the program for the final task.

Detailed on-screen instructions for each condition

LEFT HALF OF THE SCREEN (Instructions for each condition)

General instructions

On the right, you are asked to indicate whether you want to take € 6 from the pool in case you are selected as Player 1, Player 2, and Player 3, conditional on how many euros are remaining in the common pool.
Each player who takes € 6 from the common pool receives these € 6 privately.
If after all three players made their decisions there are € 0 remaining in the common pool, then there will be no payment to the players additional to their payments based on the private decisions.
If there are € 12 remaining in the common pool, then each player receives an additional € 8.

Task-specific instructions

Liberal

In this task, if there are € 6 remaining in the common pool, then there is a 50% chance that each player receives nothing extra, and a 50% chance that each player receives € 8 extra.

If this task is selected to be paid, then the game will be played based on the decisions made by you and the other group members, in the respective role that has been assigned to each of you.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, please make your choices for this task on the right side of the screen.

Dictator

In this task, if there are € 6 remaining in the common pool, then there is a 50% chance that each player receives nothing extra, and a 50% chance that each player receives € 8 extra.

If this task is selected to be paid, then the game will be played based on the decisions made by the group member that has been assigned the role of Player 1.

The payments to you depend on the role that has been assigned to you. Player 2 receives the payments for Player 2 based on the decisions made by Player 1.

Player 3 receives the payment for Player 3, based on the decisions made by Player 1.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, please make your choices for this task on the right side of the screen.

Rawls

In this task, if there are € 6 remaining in the common pool, then there is a 50% chance that each player receives nothing extra, and a 50% chance that each player receives € 8 extra.

If this task is selected to be paid, then the game will be played based on the decisions made by a randomly chosen group member ('the representative').

The payments to you depend on the role that has been assigned to you.
Player 1, 2 and 3 receive the payments for Player 1, Player 2, and Player 3, based on the decisions made by 'the representative'.

It is equally likely that you are selected as 'the representative', independent of your chances to be Player 1, 2, or 3, respectively.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, please make your choices for this task on the right side of the screen.

Solar
In this task, if there are € 6 remaining in the common pool, then there is a 50% chance that each player receives nothing extra, and a 50% chance that each player receives € 8 extra.

In this task, Player 1 has one extra option. You can choose to force Player 2 and Player 3 to leave the euros in the common pool.

Choosing this option costs € 1, which is subtracted from your pay if you are assigned and the role of Player 1.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, please make your choices for this task on the right side of the screen.

Certain
In this task, if there are € 6 remaining in the common pool, then each player receives nothing extra.

Only if there are € 12 left in the common pool will all players receive € 8 extra on top of their private payoff.

If this task is selected to be paid, then the game will be played based on the decisions made by you and the other group members, in the role that has been assigned to you.

Please raise your hand if you need further explanation from the experimenter. If you have no questions, please make your choices for this task on the right side of the screen.

RIGHT HALF OF THE SCREEN (Decision)

Solar choice screen (preceding the general choice screen in the Solar treatment)
As explained, before making a choice in each situation, you can force Player 2 and Player 3 to leave the euros in the pool, if you are selected as Player 1.

Doing so, will cost you € 1, if you are selected as Player 1.

Do you want to force Player 2 and Player 3 to leave the euros in the pool?
BUTTON: YES BUTTON: NO

General choice screen (in all treatments, in Solar this is the second decision screen)
For each situation described below, please indicate whether you take € 6 from the pool or not.

SITUATION 1: YOU ARE PLAYER 1
There are € 12 remaining in the pool, your decision: take do not take (radio buttons)

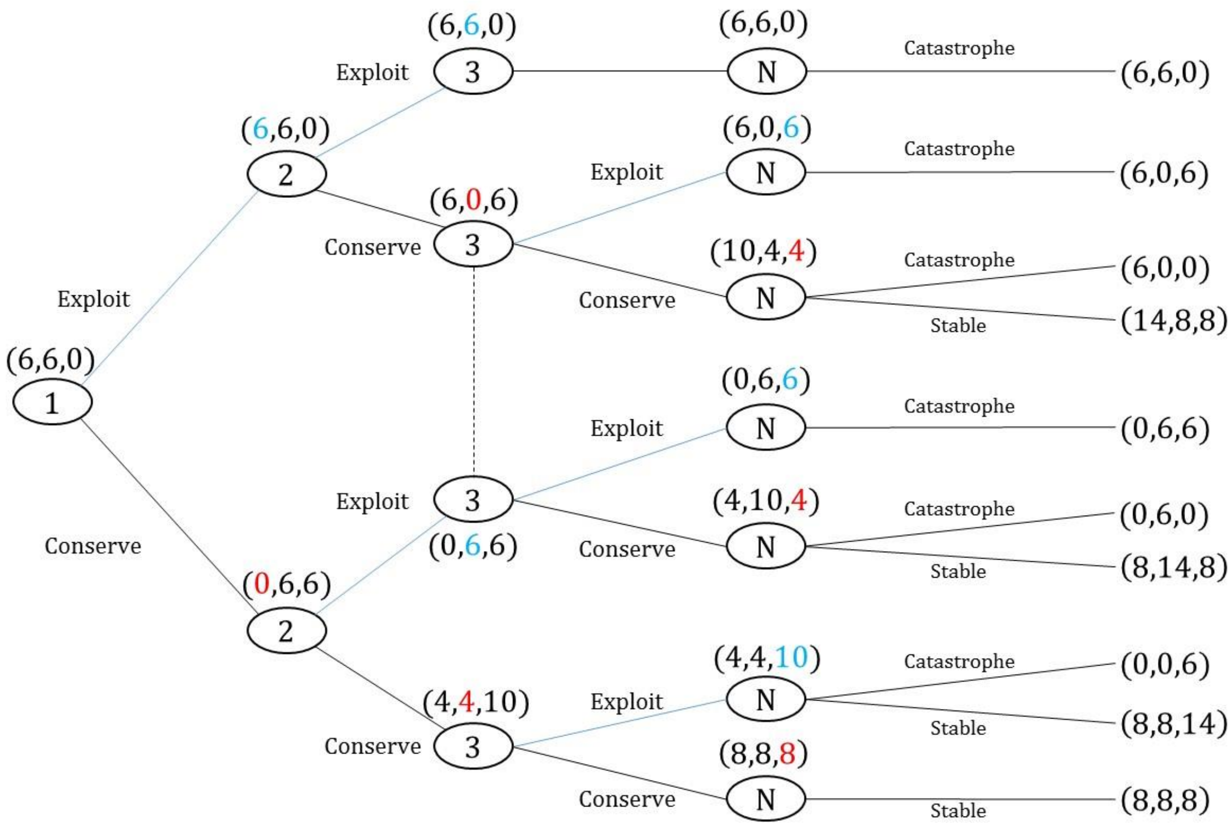
SITUATION 2: YOU ARE PLAYER 2

If there are € 12 remaining in the pool, your decision: take do not take (radio buttons)
If there are € 6 remaining in the pool, your decision: take do not take (radio buttons)

SITUATION 3: YOU ARE PLAYER 3
If there are € 12 remaining in the pool, your decision: take do not take (radio buttons)
If there are € 6 remaining in the pool, your decision: take do not take (radio buttons)

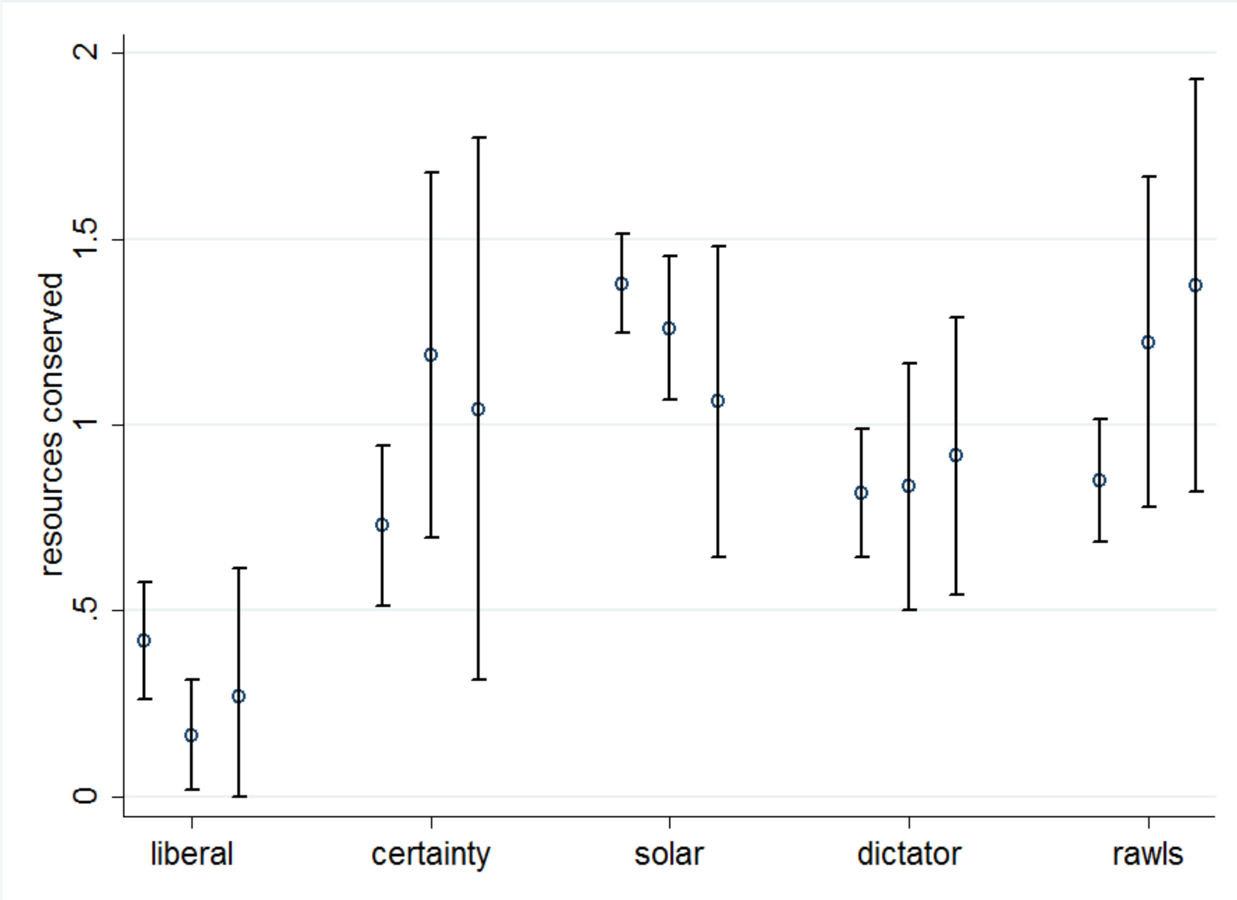
Appendix C: More Figures

FIGURE APPENDIX-1. Game tree



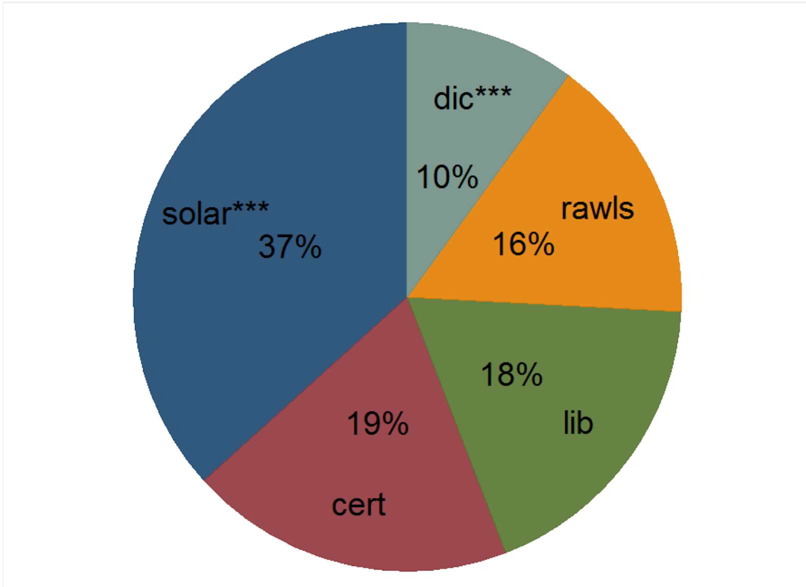
Note: The chart shows the full game tree. Three players play subsequently, choosing between exploit and conserve. In brackets the expected payoff, and actual payoffs in the last column. Blue lines present the sub-game Nash equilibrium choices. In blue the payoff for the subject choosing the Nash strategy, in red the alternative (lower) payoff.

FIGURE APPENDIX-2. Resource conservation dependence on conditions and stages



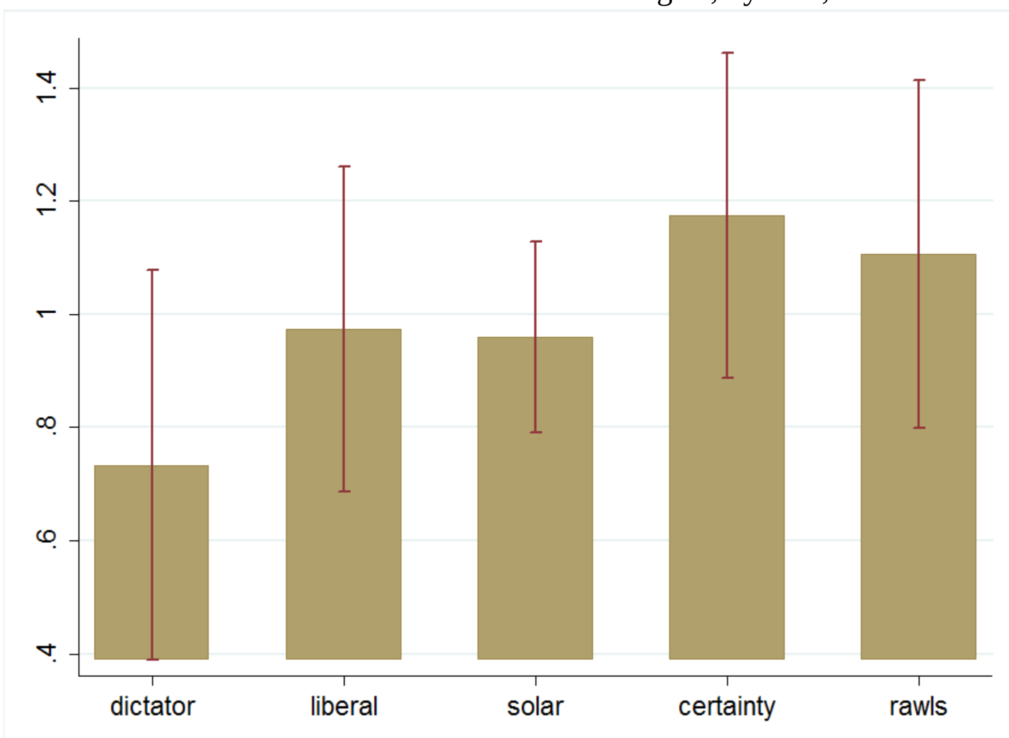
Note: The chart shows the mean and 95% confidence intervals for the resources conserved over all games in a condition. Within each condition, the first line presents the results for stage 1, the second line shows results for stage 2 (after voting), and the third line shows results for stage 3 (last iteration).

FIGURE APPENDIX-3. Vote shares, as in TABLE 4



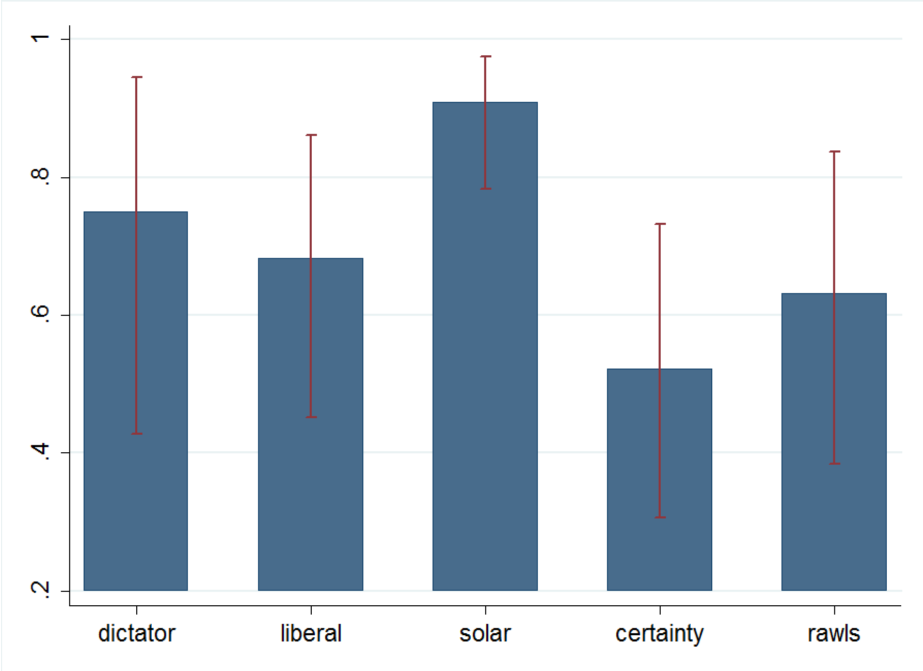
Note: The chart shows the frequency for treatment votes. Asterisks denote significant deviations from 20%.

FIGURE APPENDIX-4. Resource conservation in Stage 1, by vote, as in TABLE 4



Note: The chart shows resource conservation in stage 1, by vote, with 5-95 confidence intervals.

FIGURE APPENDIX-5. Solar choice in Stage 1, by vote, as in TABLE 4



Note: The chart shows the share of subjects using the solar choice, by vote, with 5-95 confidence intervals.