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Abstract

It is commonly found that the presence of uncertainty helps discipline economic agents in strategic contexts where incentives would otherwise induce inefficient behavior (Eso and White (2004), Bramoullé and Treich (2009)). We extend this literature by looking at a case where multiple (symmetric) equilibria co-exist. We consider a variant of the Nash demand game with (discrete) uncertainty about the value of the resource available to divide. Two type of equilibrium typically co-exist, *cautious* and *dangerous*. In contrast to the literature, strategic interactions may lead groups of risk-averse agents to take inefficiently risky decisions. We develop an experimental setting to test this finding and assess the severity of the equilibrium selection problem. We find that the (Pareto-dominant) cautious equilibria are predominantly played at the individual level. However, we observe play of dangerous equilibria even when all subjects in the group display risk aversion. The frequency of such behavior is positively correlated to the likelihood of the high value of the resource. In the aggregate, coordination failures abound but are negatively correlated to the likelihood of the high value. However, it is only when this likelihood becomes low enough that cautious behavior translates in high rates of cautious equilibria. The probability attached to the high value (resp. the low value) of the resource therefore plays an important role in achieving coordination and efficient (protective) behavior in the aggregate.

Keywords: Stochastic Nash Demand Game, Common-pool resources, Uncertainty, Threshold Effects, Experiment.

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1 Introduction

It is well known since the works of Olson (1965) and Hardin (1968) that group behavior can lead to inefficient outcomes in the form of wasted resources—like over-harvesting and over-pollution—or of forgone opportunities—e.g., under-provision of public goods—for the group. It is also increasingly established that the presence of uncertainty can help discipline risk-averse agents, thus countering the inefficiency of group behavior. Using different frameworks, Eso and White (2003), White (2004), and Bramoullé and Treich (2009) show that despite strategic motives uncertainty pushes groups of risk-averse agents toward more prudent collective choices –*precautionary behavior*. For instance, it is well-known that in a first-price auction risk-averse agents bid too aggressively in order to reduce the risk of losing the object. By contrast, when the value of the object is uncertain due to exogenous noise, as in Eso and White (2003), risk-averse agents of the DARA type bid less aggressively and are better-off as a result.[1] Eso and White (2003) call this *precautionary bidding*. Bramoullé and Treich (2009) arrive at a similar conclusion by considering a version of the commons problem where the (continuous) damage function is subject to some exogenous risk. They show that risk-averse individuals act more conservatively so as to avoid large variances in payoffs, thus mitigating the tragedy of the commons.

We extend this literature by looking at a case where multiple equilibria exist. We introduce a variant of the Nash demand game (Nash, 1950; henceforth NDG) with uncertainty about the possible values the resource can take (henceforth, stochastic NDG). Should the collective activity exceed the stock of resource available, all obtain a zero payoff. An important feature of our extension is that uncertainty is *discrete*, with two possible values of the stock—low and high—occurring with probabilities $(1-p)$ and p, respectively.[2]

The stochastic NDG captures a number of concrete situations related to the decentralized use of common resources. Taking stock of the literature on the management of common-pool resources,[3] this paper builds on two well-documented stylized facts. First, typical common-pool resources provide services subject to discontinuities, bifurcations or threshold effects that may show up rather abruptly following persistent abuses (Scheffer

[1]The increase in welfare on the bidders' side comes at the expense of the seller who would prefer a reduction in uncertainty.

[2]The standard NDG is a special case of our model where $p \in \{0, 1\}$, and this is common knowledge. Note that we model uncertainty in a discrete fashion (and with two possible states of the world) purely for practical reasons concerning the experiment. We show in the appendix that our results are qualitatively robust to the presence of an arbitrary finite number of potential thresholds. They hold as well if uncertainty concerning the location of thresholds is captured by a continuous but multimodal probability distribution.

[3]For an exhaustive literature survey and appraisal, see Elinor Ostrom (2010)'s lecture, delivered when she received the 2009 Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel.

et al. 2001). Secondly, the inherent complexity of some common-pool resources makes an assessment of discrete thresholds usually uncertain.

The climate change issue immediately comes to mind: climate scientists point to irreversible effects that may occur past a given accumulation level of greenhouse gases in the atmosphere, but disagree on the precise threshold. Hence, countries emit CO_2 without knowing which threshold is the relevant one. Despite being a long-term problem, coordinating on a high CO_2-emissions path today makes it even more difficult to meet low concentrations targets in the future. Among applications related to public health issues are epidemiological concerns: some diseases become epidemic past a threshold of infected people, with uncertainty about the threshold. Similarly, certain viruses become resistant to antibiotics past an (uncertain) level of collective use of a specific drug (for more examples we refer the reader to Laurent-Lucchetti et al, 2013). An important feature of the stochastic NDG which again fits well with these illustrative examples is that agents have the possibility of protecting themselves against risk by collectively reducing their activity.

In contrast with the aforementioned papers, in our model the presence of uncertainty can lead groups of risk-averse agents to adopt risky behavior, and inefficiently so. The realized value of the stock occurs ex-post and agents have to coordinate ex-ante on how to exploit the stock of resource appropriately. Two main sets of equilibria typically coexist (Proposition 1). In one set, *dangerous equilibria*, agents collectively exploit up to the "high" value of the stock, thus exposing themselves to a known probability of collapse. In the other set, *cautious equilibria*, agents exhibit *precautionary behavior* both at the individual and collective level by asking for a split of the "low" stock, thus guaranteeing that their claims will be met.[4,5]

From a welfare standpoint, the two types of equilibria can be ranked according to the Pareto criterion: Any cautious equilibrium is efficient and Pareto-dominates all dangerous equilibria that can be reached from it while increasing every agent's claim (Propositions 2 and 3). In particular, the *symmetric cautious equilibrium* always Pareto-dominates the *symmetric dangerous equilibrium.* Moreover, the welfare distribution of any Pareto-efficient dangerous equilibrium is severely lopsided. Thus, even though both types of equilibria may

[4]A third set of equilibria exists, *dreadful equilibria*, which coexist with the other two types of equilibria regardless of risk aversion. In a dreadful equilibrium, agents collectively claim so much of the resource that no unilateral deviation by any one agent can stop its exhaustion. Dreadful equilibria are of course always equilibria of the standard NDG.

[5]In a context relatively close to ours, Guth et al. (2004) study an NDG with two players and an uncertain surplus size. They allow each party to choose to "wait" until uncertainty is resolved before making a claim. Adding the "wait" strategy yields two equilibria in which one of the players takes almost the whole surplus, provided uncertainty is small. We deal here, however, with a class of problems in which the type of surplus to be distributed does not allow for waiting until uncertainty resolves.

coexist, a planner with a modicum of concern for distribution would choose a cautious equilibrium over a dangerous one. Simply put, all agents are better off taking less risk but strategic interactions may prevent them from doing so, thus confining them to a dangerous equilibrium. The tragedy of the commons reappears. Notice that, given the nature of uncertainty in our model, agents can alway protect themselves against uncertainty since the low value is available with certainty.

An important aspect of the characterization of equilibria is that groups of *risk-averse* individuals may engage in overly risky behavior in equilibrium because we consider threshold effects (bimodal distribution of outcomes). This adds a new layer to the coordination problem. Recall that a central caveat with the standard NDG is the size of the set of Nash equilibria and the coordination problems that may arise as a result. There, the coordination problem is, stated loosely, *"within" the set of equilibria* because agents have to coordinate on shares that sum to the (known) stock. In the stochastic NDG, the coordination problem arises within each set of equilibria, as in the standard NDG, but also *between sets of equilibria* when dangerous and cautious equilibria co-exist. We believe that, in practice, "within" coordination failures may not be so serious because agents often focus on an equal split of the targeted stock value. However, how agents solve the "between" coordination problem is far from clear, which is why we turn to an experimental test of the equilibrium predictions of the model.[6]

We develop an experimental setting to assess (i) the severity of the equilibrium selection problem in the lab, and (ii) whether uncertainty shifts agents' behavior towards cautious equilibria. Subjects play a simple stochastic NDG where the total amount to be divided can either be "high" or "low", with known probabilities. Our design varies the probability p of the high value, and we also elicit subjects' risk preferences. Our experimental results confirm the theoretical findings: both types of equilibria coexist in the data, even when all agents in a group are risk-averse. However, subjects coordinate more easily on the symmetric (Pareto-optimal) cautious equilibrium, where they collectively claim the certain amount of resource. This statement requires nevertheless some qualification. While cautious behavior is predominant at the individual level, we do witness dangerous behavior even when all agents are risk-averse in a group. The frequency of such dangerous behavior decreases in the likelihood of the high value of the resource, i.e. when co-existence of equilibria is less likely. But in the aggregate, coordination failures abound, even though these are also decreasing in the likelihood of the high value of the resource. However, it is only when this

[6]As in Barrett and Dannenberg (2012) the presence of uncertainty and thresholds transforms the traditional free-riding problem of the tragedy of the commons into a coordination problem. The fact that we consider explicitly the role of risk aversion adds another layer of complexity to the problem.

likelihood becomes low enough that cautious behavior translates into high rates of cautious equilibria in the data. The probability attached to the high value of the resource therefore plays an important role in achieving not only coordination, but also efficient behavior in the aggregate.

Related Literature: The division of private goods received much interest in the psychology literature, investigating the effects of resource uncertainty on cooperative behavior in experimental settings (Budescu, Rapoport and Suleiman, 1992; Budescu, Suleiman and Rapoport, 1995; Rapoport et al., 1992; Suleiman, Budescu and Rapoport, 1994). As in our setting, subjects were free to request as much as they wanted of a resource with the consequence that subjects received nothing if the total requests by the group exceeded the available resource. Their main finding is that as uncertainty (defined as the interval between a lower and upper bound of a uniform probability distribution) increased, subjects overestimated resource size and requested more. These findings are in line with results of experimental papers on threshold uncertainty in discrete public-good contribution games—McBride (2010) found that wider threshold uncertainty may also hinder collective action—and on common-resource problems in a dynamic setting: Fischer at al. (2004), for example, showed that an increase in uncertainty leads to overly optimistic expectations.

In these papers, and in the following literature (see for example Gustafson et al., 1999, Milinsky et al., 2008, Tavoni et al., 2011, or Barrett and Dannenberg, 2012) it is unclear why resource uncertainty affects cooperation. Gustasfon et al. (1999) states that "a reason for such overestimation may be that subjects perceive a direct relationship between the central tendency of a probability distribution and its variability. Increasing the interval between the lower and upper bound of resource size would therefore cause subjects to perceive or infer an increase of the expected value of the resource". Another suggested explanation (Rapoport et al., 1992) is that people may base their estimates of resource size on a weighted average of the lower and upper bound of its possible realization. It is furthermore assumed that the more desirable upper bound is overweighed, resulting in an upward shift of the estimates (the explanation is consistent with research demonstrating that agents tend to weight more heavily desirable outcomes, see Zakay, 1983).

Our findings shed new light on why uncertainty may lead to the subjects' collective optimism in the experimental literature: if subjects heuristically summarize uncertainty by placing weights on the lower and upper bound they effectively reason as in our setting (probability p to have the upper bound and $1-p$ to observe the lower bound). The "overestimation" of the above mentioned studies may then be due to the coordination problem between cautious and dangerous equilibria even if all agents are risk-averse. In fact, a second distinguishing feature of our experimental setup is the fact that we elicit the risk preferences of the subjects. This allows us to confirm the existence of the coordination problem and quantify its severity, because we observe many dangerous equilibria being played by risk-averse subjects. To the best of our knowledge, this is the first time that this coordination problem—resulting from a combination of uncertainty, threshold effects and risk-aversion—is identified. Finally, a set of recent papers are interested on variants of the NDG (for example, Feltovich and Swierzbinski, 2011, Anbarci and Boyd, 2011, Anbarci and Feltovich, 2012, Birkeland (2013) or Andersson et al., 2014) but none focus on the type of uncertainty we consider here. Feltovich and Swierzbinski (2011) find using experiments that introducing strategic uncertainty in a NDG has an effect on bargaining outcomes. Anbarci and Boyd (2011) and Anbarci and Feltovich (2012) introduce random implementation in the NDG: with exogenous probability q one bargainer receives her demand, with the other getting the remainder. Even more recently, Andersson et al. (2014) study strategic uncertainty theoretically. They model a player's uncertainty about another player's strategy as a probability distribution over that player's strategy set. They show that robustness to symmetric strategic uncertainty singles out the (generalized) Nash bargaining solution. By contrast, the uncertainty we introduce here is about the *size* of the resource.

The rest of the paper unfolds as follows. The upcoming section lays out the mathematical notation and the model. Section 3 states and proves our main theoretical propositions. Section 4 presents the experimental design and Section 5 the main experimental results. Section 6 brings some concluding remarks.

2 The model

We introduce in this section a stochastic version of the Nash demand game for which the value of the resource to be distributed can take two possible values, high and low. These values are common knowledge, and their attached probabilities are also known. In the appendix, we also present a more general version where multiples values are possible, and also a continuous version with multimodal distributions. The theoretical results presented in this section are robust to these extensions. Because our focus is on a test of the predictions of the model, we stick with the simpler version in this section.

Consider a finite set $N = \{1, ..., n\}$ of agents who must simultaneously decide how much of a resource they will claim for themselves. Overall demand is sustainable up to a limit, but uncertainty lies on the tipping point beyond which the intensity of use becomes unsustainable, which we model as the available resource collapsing to 0.[7] Let $h > l > 0$ be respectively the high and low values that the stock of resource can take. With probability $p \in [0,1]$, the high value h is realized, with probability $(1-p)$, the low value l is realized. We show in the appendix an extension of the model with an arbitrary finite number of potential thresholds as well as the case in which the location of thresholds is captured by a continuous probability distribution.

Denote $x_i \in [0,h]$ agent i's claim, demand or request (we use these terms interchangeably throughout the paper) on the resource, $x = (x_i)_{i \epsilon N} \in [0,h]^n$ a request vector or profile, $X = \sum_N x_i$ total demand, and $X_{-i} = \sum_{j \neq i} x_j$ the sum of all agents' claims except agent i's. Given a profile $x \in [0,h]^n$, we also use the notation $x_{-i} = (x_j)_{j \neq i}$ for the profile of demands of agents other than i. Likewise, we use x_T for the profile of demands of agents that belong to T, and $x_{-T} = (x_j)_{j \in T}$ for the profile of demands of agents that belong to $N \setminus T$, where $T \subseteq N$. The utility agent i derives from being delivered her request x_i is given by $u_i(x_i)$, where the function $u_i(\cdot)$ is concave and nondecreasing. Note that concavity of the utility function implies that agents are risk-averse or risk-neutral. Reaching consumption level x_i is of course conditional on total demand not exceeding the threshold; otherwise all agents get zero utility ($u_i(0) = 0$ for all i).

Agent i's expected payoff in this *Stochastic Nash Demand Game (Stochastic NDG)* is now given by:

$$v_i(x_i, X_{-i}) = u_i(x_i)\mathbb{I}(X \leq l) + p u_i(x_i)\mathbb{I}(l < X \leq h), \tag{1}$$

where $\mathbb{I}(\cdot)$ indicates whether the condition within parentheses holds ($= 1$) or not ($= 0$). Notice that the classical NDG is the special case of a Stochastic NDG in which $p \in \{0,1\}$.

Nash equilibrium: A profile of claims $x \in [0,h]^n$ is a (pure-strategy) *Nash equilibrium* if for all $i \in N$, and all $x'_i \in [0,h]$:

$$v_i(x_i, X_{-i}) \geq v_i(x'_i, X_{-i}). \tag{2}$$

Strong Nash equilibrium: A profile of claims $x \in [0,h]^n$ is a (pure-strategy) *strong Nash equilibrium* if there does not exist $T \subseteq N$, and $x'_T \in [0,h]^{|T|}$ such that,

$$v_i(x'_T, x_{-T}) \geq v_i(x_T, x_{-T}) \text{ for all } i \in T \text{, and} \tag{3}$$

$$v_j(x'_T, x_{-T}) > v_j(x_T, x_{-T}) \text{ for some } j \in T. \tag{4}$$

[7]One interpretation is that agents are sufficiently long-lived to deem the utility from immediate unsustainable resource consumption negligible compared to the lifetime utility of sustained consumption.

This completes the description of the model. We now proceed to the derivation of our main results.

3 Theoretical results

We first characterize the set of Nash equilibria of the stochastic NDG. Later, we will analyze the efficiency properties of these equilibria.

3.1 Nash equilibria

An agent i's best response strategy as follows. First, consider the case where $X_{-i} > l$:

a) If $X_{-i} \leq h$, agent i can do no better than to request $x_i = h - X_{-i}$ because the remaining agents already collectively demand more than the sustainable threshold l.

b) If $X_{-i} > h$, however, agent i can claim any amount $x_i \geq 0$, because she will end up with a payoff of zero anyway.

Next, consider the case where $X_{-i} \leq l$:

a) If $u_i(l - X_{-i}) \geq pu_i(h - X_{-i})$, agent i does best by claiming $x_i = l - X_{-i}$. Requesting the safe amount $l - X_{-i}$ in this case yields a higher (certain) utility than demanding the larger but risky amount $h - X_{-i}$.

b) Similarly, if $u_i(l - X_{-i}) < pu_i(h - X_{-i})$, agent i's best response is $x_i = h - X_{-i}$.

This description of the best-response strategies shows that three sorts of Nash equilibria are possible: (1) *cautious equilibria*, in which agents collectively demand the highest safe level, $X = l$; (2) *dangerous equilibria*, where agents together request the risky upper ceiling, $X = h$, and face a probability $1 - p$ of exhausting the resource; and *dreadful equilibria*, wherein everyone's claim is so high—$X_{-i} > h$ for all i—that no individual adjustment can avoid their collapse. We define these formally below.

Cautious Equilibrium: An equilibrium profile $x \in [0, h]^n$ is a *cautious equilibrium* if $X \leq l$.
Notice that for any cautious equilibrium, payoffs are then always positive regardless of p because l is available with certainty—i.e., $v_i(x_i, X_{-i}) = u_i(x_i) > 0$ for all $i \in N$.

Dangerous Equilibrium: An equilibrium profile $x \in [0, h]^n$ is a *dangerous equilibrium* if $l < X \leq h$.

Notice that for any dangerous equilibrium, $v_i(x_i, X_{-i}) = pu_i(x_i)$ for each $i \in N$.

Dreadful Equilibrium: An equilibrium profile $x \in [0, h]^n$ is a *dreadful equilibrium* if $X_{-i} > h$ for all $i \in N$.

Dreadful equilibria yield zero utility to all. These equilibria already exist in the classical NDG and are therefore not the focus of our analysis.

Notice that no Nash equilibrium exists in which agents collectively ask for less than l or strictly between l and h. Moreover, cautious, dangerous and dreadful Nash equilibria can coexist, despite the fact that all agents are risk averse. This contrasts with the findings reported so far in the literature (see Bramoullé and Treich 2009, for example).

Example 1. *Let there be only two agents, with identical utility function* $u_i(x_i) = \sqrt{x_i}$ *for* $i = 1, 2$. *Suppose* $l = 0.8$, $h = 1$, *and* $p = 0.8$. *The strategy profile* $x = (0.5, 0.5)$ *is a dangerous equilibrium because* $v_i(0.5, 0.5) = 0.7 \cdot 0.8 = 0.56 > v_i(0.3, 0.5) = 0.54$ *for* $i = 1, 2$. *At the same time, the profile* $x' = (0.4, 0.4)$ *is a cautious equilibrium because* $v_i(0.4, 0.4) = 0.63 > v_i(0.6, 0.4) = 0.77 \cdot 0.8 = 0.62$ *for* $i = 1, 2$; *and* $x'' = (1, 1)$ *is also clearly an equilibrium, a dreadful one which brings each agent's payoff to* 0.[8] ◇

In order to grasp the conditions underlying the existence of each type of Nash equilibria, we introduce an extra piece of notation. Let $0 \leq \overline{X}_i \leq l$ refer to the *cut-off demand level* of the other agents such that:

$$\begin{aligned} u_i(l - X_{-i}) &> pu_i(h - X_{-i}) \quad \text{if } X_{-i} < \overline{X}_i, \\ u_i(l - X_{-i}) &< pu_i(h - X_{-i}) \quad \text{if } X_{-i} > \overline{X}_i. \end{aligned} \tag{5}$$

This allows us to make the following preliminary statement.

Lemma 1. *For each* i, *there always exists a unique cut-off demand level,* $\bar{X}_i$.

Proof. Let $f_i(X_{-i}) \equiv u_i(l - X_{-i}) - pu_i(h - X_{-i})$. Clearly, $f_i'(X_{-i}) = -u_i'(l - X_{-i}) + pu_i'(h - X_{-i}) < 0$ because the function u_i is concave. If $f_i(0)$ is nonpositive, set $\bar{X}_i = 0$. If $f_i(0)$ is positive, the fact that $f_i(a) < 0$ and that $f_i(.)$ is decreasing and continuous entails that there is a unique $\bar{X}_i > 0$ such that $f_i(\bar{X}_i) = 0$, $f_i(X_{-i}) > 0$ if $X_{-i} < \bar{X}_i$, and $f_i(X_{-i}) < 0$ if $X_{-i} > \bar{X}_i$. □

[8] Although we exclude such risk attitudes for reasons of tractability, note that all three types of equilibria may also coexist with only risk-loving agents. To see this, simply modify the Example by supposing that $i = 1, 2$, $u_i(x_i) = x_i^2$, and $p = 0.4$. One can check that $x = (0.5, 0.5)$ is a dangerous equilibrium, $x' = (0.4, 0.4)$ is again a cautious one, and $x'' = (1, 1)$ is a dreadful equilibrium.

The following proposition characterizes the existence of cautious and dangerous equilibria.

Proposition 1. *The game always admits at least one non-dreadful equilibrium. More precisely,*

i) *A cautious equilibrium exists if and only if* $\sum_{i \in N} \bar{X}_i \geq (n-1)l$;

ii) *A dangerous equilibrium exists if and only if* $\sum_{i \in N} \bar{X}_i \leq (n-1)\,h$;

iii) *Cautious and dangerous equilibria coexist if and only if* $(n-1)l \leq \sum_{i \in N} \bar{X}_i \leq (n-1)\,h$.

Proof. Part i): By the above description of best-response strategies, a strategy profile x is a cautious equilibrium if and only if

$$\begin{cases} X_{-i} \leq \bar{X}_i & \text{for all } i \in N \\ \sum_j x_j = l \end{cases} \tag{6}$$

Using the fact that $X_{-i} = l - x_i$ and adding up all the inequalities in (6), we have that $\sum_i \bar{X}_i \geq (n-1)l$. Conversely, if $\sum_i \bar{X}_i \geq (n-1)l$, one can always find a vector x that satisfies (6).

Part ii): Similarly, a strategy profile x is a dangerous equilibrium if and only if

$$\begin{cases} X_{-i} \geq \bar{X}_i & \text{for all } i \in N \\ \sum_j x_j = h \end{cases} \tag{7}$$

Using the fact that $X_{-i} = h - x_i$ and adding up all the inequalities in (7), we have that $\sum_i \bar{X}_i \leq (n-1)h$. Conversely, if $\sum_i \bar{X}_i \leq (n-1)h$, one can always find a vector x which satisfies (7).

Part iii) follows trivially. □

Figure 1 illustrates the sets of equilibria in the two-agent case. These sets depend on the location of the cut-offs $\bar{X}_i$, which in turn depends on the lower bound l, the probability p, and the agents' respective utility functions $u_i(\cdot)$.

We now discuss a few comparative statics arguments regarding the probability p of the high value occurring and the intensity of the agents' risk-aversion. From Proposition 1, a higher value of p means a lower value of the cut-off $\bar{X}_i$, owing to the fact that claiming the risky amount of resources, $h - X_{-i}$, has become relatively more tempting. As a result, the set of dangerous equilibria expands, in the sense of inclusion, whereas the set of cautious equilibria shrinks as p increases.

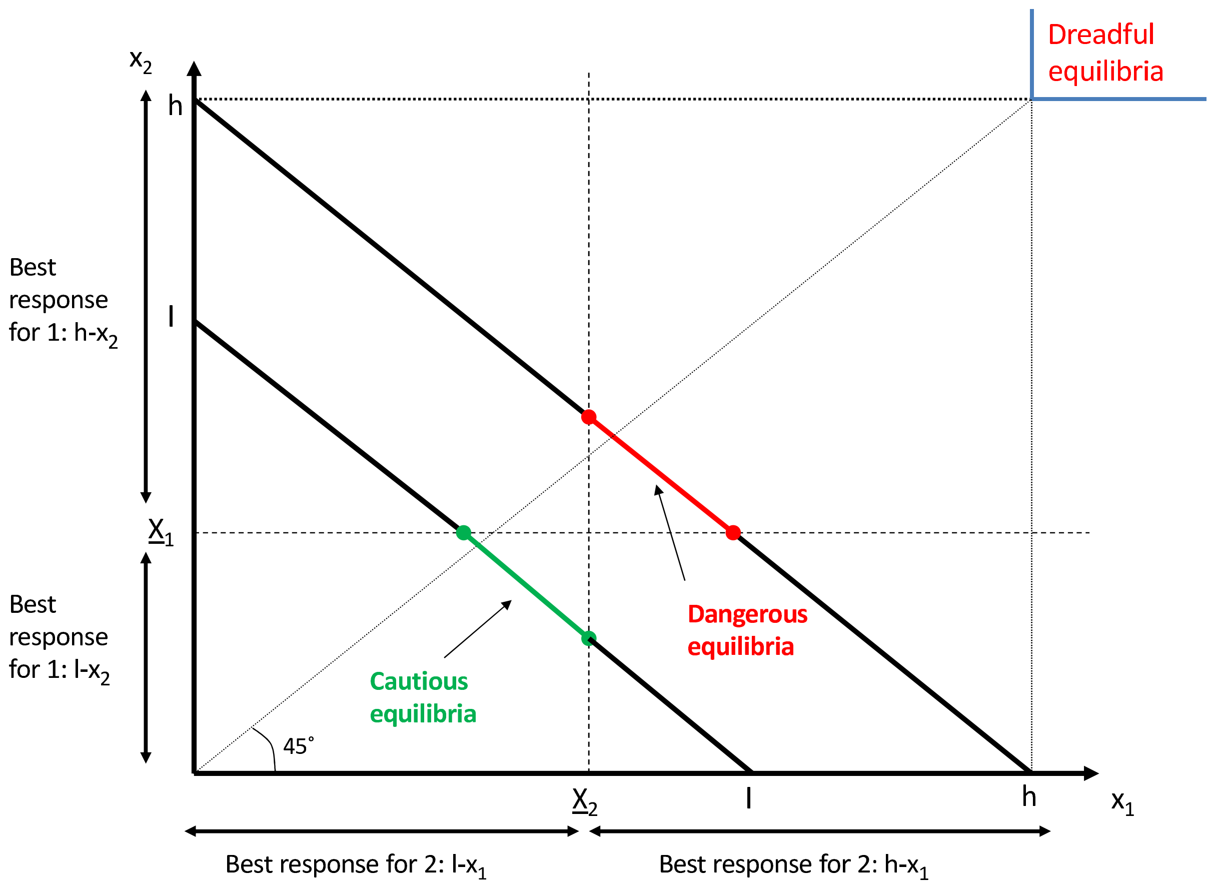


Figure 1: The two agents case

Remark 1. *Focusing on symmetric equilibria: the symmetric dangerous equilibrium exists if* $u_i\left(l - \frac{(n-1)h}{n}\right) \leq pu_i\left(\frac{h}{n}\right)$ *for all* $i \in N$*. Clearly the inequality does not hold when* $p = 0$ *and is true when* $p = 1$*. Hence there exists a* $\underline{p_i}$ *such that* $u_i\left(l - \frac{(n-1)h}{n}\right) = \underline{p_i}u_i\left(\frac{h}{n}\right)$*. It follows that for high values of* p*, i.e.* $p \geq \underline{p_i}$ *agent* i *does not wish to deviate from the symmetric Dangerous strategy. Similarly a cautious equilibrium exists if* $u_i\left(\frac{l}{n}\right) \geq pu_i\left(h - \frac{(n-1)l}{n}\right)$ *for all* $i \in N$*. The inequality clearly holds at* $p = 0$ *and not at* $p = 1$*. Hence, there exists a* $\overline{p_i}$ *such that* $u_i\left(\frac{l}{n}\right) = \overline{p_i}u_i\left(h - \frac{(n-1)l}{n}\right)$ *for all* $i \in N$*. It follows that for low values of* p*, i.e.* $p \leq \underline{p_i}$ *agent* i *does not wish to deviate from the symmetric Cautious strategy. Observe that if* u_i *is concave, then* $\underline{p_i} \leq \overline{p_i}$*.*[9] *Therefore, in the range* $\underline{p_i} \leq p \leq \overline{p_i}$*, a risk-averse agent can be part of both the symmetric Cautious and the symmetric Dangerous equilibria.* ◇

Similarly, if agent i becomes more risk-averse—so that the coefficient of absolute risk aversion $u_i''(\cdot)/u_i'(\cdot)$ increases, say—the cut-off $\bar{X}_i$ increases because a certain amount of resources, $l - X_{-i}$, is now relatively more attractive. It follows from Proposition 1 that the set of cautious equilibria expands while the set of dangerous equilibria shrinks as agents become more averse to risk, all else equal.

Example 2. *Let* $u_i(x_i) = (x_i)^\alpha$*,* $0 < \alpha \leq 1$*, for all* $i \in N$*. With this functional form, a symmetric dangerous equilibrium exists if* $p^{1/\alpha} \geq \left(\frac{nl-(n-1)h}{h}\right)$*. Similarly, a symmetric cautious equilibrium exists if* $p^{1/\alpha} \leq \left(\frac{l}{nh-(n-1)l}\right)$*. It is noteworthy that* $p^{1/\alpha}$ *is increasing in both* p *and* α*. This implies that if* p *and* α *are such that both types of equilibria coexist, by decreasing* p*—and letting* α *constant—we end up with only the symmetric cautious equilibrium remaining. Similarly, by decreasing* α*—letting* p *constant—we eliminate the dangerous equilibrium while keeping the symmetric cautious one.* ◇

3.2 Efficiency

We now assess the efficiency properties of each type of equilibria. It turns out that cautious equilibria are not only Pareto-efficient, they are also strong Nash equilibria. The following proposition determines whether dreadful and cautious equilibria are strong in this sense.

Proposition 2. *Cautious equilibria are strong, but dreadful equilibria are not.*

[9] Adding $\frac{n-1}{n}(h-l)$ to the argument on both sides of $u_i\left(l - \frac{(n-1)h}{n}\right) = \underline{p_i}u_i\left(\frac{h}{n}\right)$ yields, by concavity of u_i that $u_i\left(\frac{l}{n}\right) > \underline{p_i}u_i\left(h - \frac{(n-1)l}{n}\right)$. Therefore, $\underline{p_i} \leq \overline{p_i}$.

Proof. From a dreadful equilibrium, any group deviation leading to a cautious or a dangerous strategy profile, be it a deviation by the entire set of players, obviously brings a higher payoff to all agents in the coalition. Hence, dreadful equilibria are not strong.

The proof that cautious equilibria are strong proceeds by contradiction. Let $x \in \mathbb{R}^n_+$ be a cautious equilibrium, and suppose there exists another strategy profile x' and a coalition $T \subseteq N$ such that $x'_k = x_k$ for all $k \notin T$, $v_i(x') > v_i(x)$ for some $i \in T$, and $v_j(x') \geq v_j(x)$ for all $j \in T$. Because the utility functions u_j's are increasing, it must be the case that $\sum_{j\in T} x'_j > \sum_{j \in T} x_j$ and $x'_j \geq x_j$ for all $j \in T$. Now, consider an agent $j \in T$ such that $X'_{-j} > X_{-j}$. For this agent, demanding $x'_j = l - X'_{-j}$ or less leads to a lower payoff than before; her best response must be $x'_j = h - X'_{-j}$. We then have that $v_j(x'_j, X'_{-j}) = v_j(h - X'_{-j}, X'_{-j}) < v_j(h - X_{-j}, X_{-j}) \leq v_j(x)$, where the last inequality holds because x is a Nash equilibrium. Agent j is thus worse off under x' than under x, which contradicts the initial assertion. □

This proposition entails that all cautious equilibria are Pareto efficient. Furthermore, any cautious equilibrium Pareto-dominates all dreadful ones. The status of dangerous equilibria is not so clear-cut, however. The following result shows that a cautious equilibrium Pareto-dominates all dangerous equilibria that can be reached from it while increasing every agent's claim.

Proposition 3. *Let the strategy profile x be a dangerous equilibrium. Any cautious equilibrium x' such that, for some subset $T \subseteq N$,*

$$\begin{aligned} x'_i &= x_i - \alpha_i \qquad \text{for all } i \in T, \text{ and} \\ x'_i &= x_i \qquad \text{for all } i \notin T, \end{aligned} \tag{8}$$

with $\alpha_i \geq 0$ for all $i \in T$ and $\sum_i \alpha_i = h - l$, Pareto-dominates x.

Proof. Suppose a dangerous equilibrium x and a cautious equilibrium x' verifying condition (8). For all $i \in T$, we have that

$$\begin{aligned} u_i(x'_i) &\geq pu_i(x'_i + h - l) \\ &= pu_i(x_i + \sum_{j \neq i} \alpha_j) \\ &> pu_i(x_i). \end{aligned}$$

The first inequality holds because x' is itself a Nash equilibrium. The second (strict) inequality follows from the fact that $\sum_{j\neq i} \alpha_j > 0$, for $\sum_{j \neq i} \alpha_j = 0$ would mean that x is not a Nash equilibrium (since the cautious equilibrium x' could then be reached from it through a unilateral move by agent i). □

An important consequence of Proposition 3 is the following: if dangerous and cautious equilibria co-exist, not only a symmetric cautious is Pareto efficient and strong, but then the symmetric dangerous equilibrium is always Pareto inefficient.

3.3 From Theory to Evidence

Our theoretical results reveal that a collection of risk-averse individuals may engage in overly risky behavior in equilibrium. This adds a new layer to the coordination problem: not only must players coordinate "within" the set of equilibria whose demands sum to a given level, say l, but they must also coordinate *between* sets of equilibria—those summing to l and those summing to h—when dangerous and cautious equilibria co-exist.

In practice, "within" coordination failures may not be so serious because agents often focus on symmetric share profiles where each asks for an equal split of the targeted stock value. However, how agents solve the "between" coordination problem is far from clear, which is why we turn to experiments. We shall investigate the following three hypotheses:

1) *Cautious and dangerous equilibria can coexist even though all agents are risk averse* (consistent with Proposition 1): risk averse players may end up in a dangerous equilibrium *even if* a cautious equilibrium exist (coordination problem). In other words, we expect to find that risk aversion is uncorrelated to the equilibrium play in the experiment.

2) *We should observe more cautious equilibria for low value of p and more dangerous equilibria for higher value of p* (consistent with Remark 1). We thus expect to find a higher rate of cautious equilibria in treatments with low p than in the treatment with higher p (and conversely for dangerous equilibria). Furthermore, when both types of equilibria coexist, cautious equilibria may be more likely to emerge (due to their appealing robustness and welfare properties; consistent with Propositions 2 and 3): the fact that the symmetric cautious equilibrium dominates the symmetric dangerous may render it focal. We should thus observe a higher rate of cautious equilibria across all treatments, and this should get stronger for lower values of p.

3) *Coordination becomes more difficult when co-existence of equilibria is more likely* (consistent with an increase in between-coordination failures when both equilibria exist). Hence, we should observe less equilibria (of both types) in treatment with intermediate and high values of p, when co-existence is more likely. This coordination problem should disappear for lower values of p, where only cautious equilibria exist (or for very high values of p, where only dangerous equilibria exist).

4 Experimental Design

The experiment took place in the spring of 2014 at the experimental lab of the University of Bern. Participants were recruited via ORSEE (Greiner, 2004) from the student pool at the University of Bern. The experiment lasted for up to 60 minutes per session and consisted of three different treatments, three sessions for each treatment, and each session involving different participants. Participants earned an average of 32 CHF for their participation (including a 5 CHF show-up fee)—roughly $31US).

We ran three treatments, each with three sessions of twelve subjects for a total of 108 subjects. Our treatment variable is the probability p for the high value of the resource. Each session consisted of two parts. Part 1 was a 10-period version of a Stochastic NDG with fixed probability p for the high value of the resource, fixed $h = 24$ while $l = 18$ for all treatments, all public knowledge. There is no framing and the wording is neutral—see attached instructions in the Appendix. The second part of the experiment is divided into two subparts in which subjects face two different price lists. In the first subpart (called Part 2), subjects face a standard risk-preference elicitation questionnaire (Holt and Laury, 2002). In the second subpart (called Part 3), subjects face a tailor-made questionnaire to evaluate their propensity to play symmetric cautious equilibria, i.e. we evaluate there the probability p at which a subject would play a symmetric cautious equilibrium given that the others do as well. We will use mostly the latter task. Treatments 1 to 3 had values of $p = 0.7, 0.5$ and 0.3, respectively. Let these treatments be labeled T07, T05 and T03, respectively.

Each session is composed of twelve subjects who are divided into two silos (blocks) of six for the first part of the experiment. Subjects in different silos never interact with one another. In Part 1, at the beginning of each period, participants are assigned randomly into groups of three. Groups are reshuffled each period and identities are unknown throughout to minimize on reputation effects. Given the silos construction, we have six independent observations per treatment (two per session). In each period, groups play the Stochastic NDG given the probability p that prevails in the session. The probability p is public knowledge among participants. For Part 1, subjects are informed that they will be paid three randomly chosen periods out of the ten periods played. With this, we aim at forcing subjects to be focused on their choices in each period, as well as reducing hedging and

Treatment	T07	T05	T03
Probability	0.7	0.5	0.3
Sessions	3	3	3
Silos	2	2	2
Subjects per Silos	6	6	6
Subjects	36	36	36

Table 1: Experimental Design

repeated-game effects. When moving to the next part, subjects are informed that only one of the subparts (Part 2 or Part 3) will be randomly chosen to be payoff-relevant. At the beginning of the experiment, subjects are told that the experiment will be composed of three different parts, but are not given any information regarding these until they actually take place.

Before the start of each session, participants are given a detailed set of instructions explaining the first part of the experiment (the probability p, the payoffs, etc.) and summarizing the Stochastic NDG in which they will take part. Control questions assess the understanding by participants. The experiment does not start until all participants have answered correctly the control questions. Part 1 lasts for ten periods. Each period is decomposed into two steps. First, participants are asked to give an estimation of the sum of the demands that the other two in their groups will ask for. We interpret this as the belief that participants form regarding the behavior of their group members. This belief elicitation is incentivized. If a participant correctly estimates the demand of the others in his group, he gets 1.5 extra experimental dollars. If his estimation deviates by one, he receives only 1 experimental dollar. If his estimation differs by 2 points, he gets 0.5 experimental dollar. If it differs by more, he gets nothing. In the second step, each participant is asked to play the stochastic NDG by submitting an integer demand between zero and 24. At the end of each period, each participant is informed about the total demand in his group as well as his payoff in this given period.

5 Experimental Results

From now on, we will call a demand profile x *consistent with a Nash equilibrium* whenever demands sum to 18 or 24, and this for all of our treatments. Likewise, we will talk about a *symmetric individual Nash strategy* for subject i if his demand x_i is either 6 or 8, and this for any of our treatments.

We start with an overview of the statistical observations, pointing at our main results

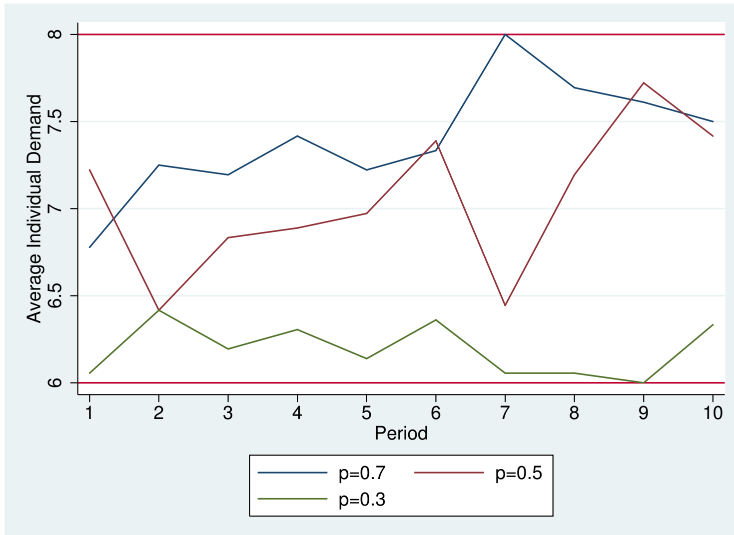


Figure 2: Average individual demand by period

before exposing them formally. Our first result is that both types of equilibria are played when they coexist, *independently* of the risk aversion of players (Result 1). We then stress that, overall, equilibrium play is mostly cautious. We show that the tendency to play cautious decreases with p while the tendency to play dangerous increases with p but that Cautious is more played overall (Result 2). Finally we establish that coordinations failure are more prevalent when p increases due to an increase in between-coordination failure (Result 3).

5.1 Preliminary remarks

We give here an overview of important trends coming out of our experiment. This will help us forming some first intuitions regarding the three central results of the experiment.

Average demands First, we observe that behavior differs across treatments, both at the individual and group levels. Figure 2 shows average individual demands over time by treatments—the two horizontal lines at 8 and at 6 stand for the dangerous and cautious symmetric demands, respectively. Treatment T03 stands in contrast with the other two treatments. Demand there is always between 6 and 6.5 after Period 1 while demand in T07 is clearly increasing towards 8. T05 stands in the middle with a convergence toward 8. Hence as we move across treatments we see a shift away from the cautious strategy.

However, average demands are not necessarily the best measure of behavior to consider in our set up since they are silent regarding the type of strategy chosen by participants

Treatment	Cautious NE	Dangerous NE	Coord. failure rate $= 100 - CNE - DNE$
T03	65%	5%	30%
T05	37.5%	11.7%	50.8%
T07	5.8%	22.5%	71.7%

Table 2: Equilibria Rates by Treatments

(as well as equilibrium versus non-equilibrium behavior). Indeed, Result 1 will confirm that both types of strategies (cautious and dangerous) coexist in the data, especially in the treatment $p = 0.7$.

Nash Equilibria Over all treatments almost half of the outcomes are Nash equilibria (49%). The rate of Nash equilibria is 28.3% in T07, and climbs to 49% in T05 and 70% in T03. The majority of these equilibria are symmetric: 75% of all equilibria are symmetric when $p = 0.7$, 76% when $p = 0.5$ and 85% when $p = 0.3$. We will thus focus on these symmetric equilibria for the rest of the analysis.

Table 3 hints at two important features of our results. We can see that two types of coordination failures are more and more salient as p increases: As we move across treatments groups focus less and less on the (Pareto-dominating) cautious equilibrium (Result 2) and, most importantly, focus less and less on any equilibrium at all (Result 3).

Risk aversion and co-existence of equilibria We turn to describing Part 3 of the experiment. The purpose of this task is (i) to elicit risk preferences and (ii) test for the existence of symmetric equilibria in our set up. Subjects have a list of 10 decisions to make, each decision involving the choice between two lotteries—A and B—where A always brings a certain amount of 6 and B brings 12 with uncertainty. The probability to obtain 12 in decision B is equal to 0.1 for decision 1, 0.2 for decision 2,... and 1 for decision 10. We simply record the decision at which a subject switches between lottery A and B.[10] The number of successive choices is indicative of the attitude towards risks of subjects: the risk-averse switching between lotteries A and B happens after the fifth decision (the fifth decision is having 6 with certainty or 12 with probability 0.5). This task also allows us to highlight the existence of symmetric dangerous and cautious equilibria per treatment. Notice that an agent switches at the probability where having 12 with uncertainty brings a higher expected payoff than having 6 with certainty. This coincides with the probability at which an agent with a belief that the others collectively play 12 switches away from the

[10] In total, 10 subjects out of 108 (and no more than 3 per session per treatment) exhibited more than one switch. We excluded those subjects from the sample whenever necessary as is standard in the literature.

cautious play.

Hence, the proportion of players who *did not* switch at a given probability is willing to play a symmetric cautious equilibrium if they expect others to do so. Furthermore, we can also infer a lower bound of the proportion of players willing to play the symmetric dangerous strategy: when an agent i switches at a probability p or below we know that $u_i(6) < pu_i(12)$. This condition, coupled with the concavity of $u_i(.)$, implies that $u_i(2) < pu_i(8)$ holds when an agent i switches at p or below. Notice that this last condition guarantees that agent i would play a symmetric dangerous strategy if she expects others to do so. In other words, the proportion of players switching at p *is willing* to play a symmetric dangerous strategy and *is not willing* to play a symmetric cautious strategy at this probability or a higher one. Table 4 shows the distribution of the *number of safe choices* in the experiment (pooled data) and the proportion of players willing to play a symmetric equilibrium (as detailed above).

Risk Aversion The average number of safe choices is at 6.99 over all treatments, indicating moderate/substantial risk-aversion on the part of the subject.[11] This means that on average, subjects chooses option B at the 7th decision only. There seems to be no significant difference across treatments in the average number of safe choices made at the block level (Kruskall-Wallis test, p-value = 0.484).[12] A Wilcoxon signed-rank test cannot reject H0 that the median of the distribution of average number of safe choices is 7 in, respectively, T07 (p-value = 0.2), T05 (p-value = 0.599), and T03 (p-value =0.913).[13] Less than 15% of players switched at the 5th decision (the risk neutral one) and 3% switched below (pointing at almost no risk loving behavior). These results show that players adopt behaviors consistent with risk averse preferences.

Existence of symmetric equilibria Table 4 allows us to estimates the proportion of players willing to play the symmetric cautious and the symmetric dangerous strategy in each treatment *if they expect others to do so.* Hence it will be indicative about the *existence* of both types of equilibria per treatment.

[11] The average risk indexes are, respectively, 6.71 in T07, 7.23 in T05, and 7.05 in T03.

[12] We also compute Mann-Whitney tests for pairwise comparisons. The null hypothesis of identical medians of the distributions of average number of safe choices can never be rejected. For T07-T05, p-value= 0.227; T07-T03, p-value=0.687; for T05-T03, p-value=0.464

[13] It is noteworthy that the Holt and Laury procedure (Holt and Laury, 2002)—Part 2 of our experimental protocol—leads to consistent results (i.e., agents are on average mildly risk averse and the distribution of risk preferences is similar in each treatment): The average number of safe choices is, respectively, 6.3 for T07, 6.1 for T05, and 6.3 for T03.

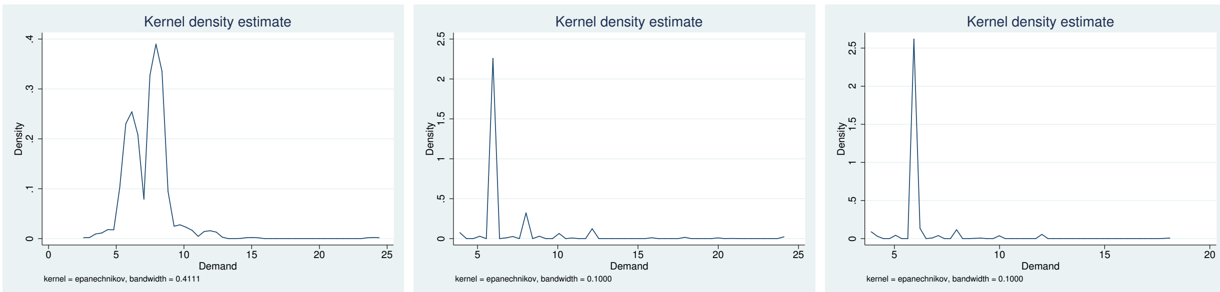
Safe choice	Probability	Proportion switching	Cautious	Dangerous
0	0	0%	100%	0%
1	0.1	0%	100%	0%
2	0.2	0%	100%	0%
3	0.3	0%	100%	0%
4	0.4	2.78%	97.22%	2.78%
5	0.5	12.04%	85.18%	14.82%
6	0.6	30.56%	54.62%	45.38%
7	0.7	27.78%	26.84%	73.16%
8	0.8	12.04%	14.8%	85.2%
9	0.9	4.63%	10.17%	89.83%
10	1	10.17%	0%	100%

Table 3: Number of safe choices and its mapping to symmetric equilibria existence

Overall, 73% of the agents switched at 7 or below. Hence, at a probability of 0.7 (Treatment T07), 27% of the subjects would play a symmetric cautious strategy if they expected others to do so and at least 73% would play a dangerous strategy. We thus expect to observe both strategies in treatment T07, with more dangerous than cautious. Similarly, 15% of subjects switched at 5 or below, hence 85% would play a cautious strategy and at least 15% would play a dangerous one at $p = 0.5$ (Treatment T05). We thus expect many cautious and few dangerous strategies in this treatment. Finally, no agent switched at 3: all agents would play 6 instead of 12 when $p = 0.3$ (Treatment T03): we should observe almost no dangerous strategies and many cautious strategies. Of course, in the stochastic NDG subjects have more strategies at their disposal than playing "6" or "12". It is thus likely that we will observe less occurrences of both symmetric strategies than predicted above. Furthermore, when equilibria co-exist an agent will choose to play "cautious" or "dangerous" depending on her belief about the quantity played by others. We will detail this feature in result 3.

Result 1: Cautious and Dangerous equilibria co-exist even if agents are risk averse.

Cautious and Dangerous strategies coexist for $p = 0.5$ and $p = 0.7$. We now turn to the distribution of the individual demands to see if the predictions exposed in Table 4 translate in the Stochastic NDG. In Figure 4, we use a Kernel density estimation to analyze the distribution of individual demands. We observe a clear bimodal distribution in demands when $p = 0.7$, confirming the trend observed in the task described above: agents



(a) $p = 0.7$ (b) $p = 0.5$ (c) $p = 0.3$

Figure 3: Individual demand by treatment.

focus on playing both 6 or 8 in this treatment. We interpret this play as consistent with the co-existence of both types of equilibrium strategies (cautious and dangerous) in this treatment. We observe a strong shift at the individual level toward 6 when $p = 0.5$ (with a little bump around "8") and an even stronger shift at $p = 0.3$.

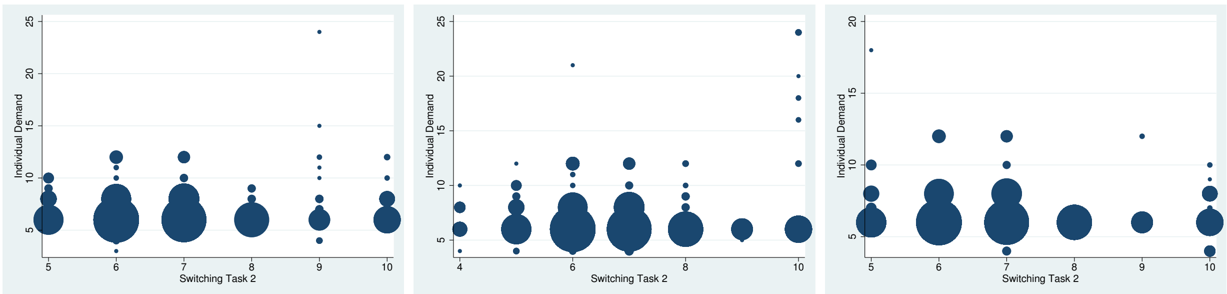
Table 5 shows the rate of symmetric Nash strategies (individual demand equals 6 or 8). First, we see that both types of strategies are played in T07: 48% of individual plays are equal to 8 (the symmetric dangerous play) and 30% are equal to 6 (the symmetric cautious play). In the two other treatments, the rate of cautious strategies increases and the rate of dangerous diminishes: 10% of individual plays are equal to 8 and 69% are equal to 6 in the T05. Finally, 4% of individual plays are equal to 8 and 87% are equal to 6 in T03. Interestingly, these proportions are not too far off the predicted ones we obtained in part 3.[14]

Cautious or Dangerous Strategy	**0.3**	**0.5**	**0.7**
6	313	250	110
8	13	35	173
No. Observations	326	285	283
Proportions	0.91	0.79	0.78

Table 4: Distribution of Symmetric Nash Strategies

At the group level, 22.5% of observations are dangerous equilibria and 5.83% are cautious equilibria in T07, 11.67% of observations are dangerous equilibria and 37.5% are cautious equilibria in T05 treatment. Finally, 5% of all observation are dangerous equilibrium and 65% are cautious equilibrium in T03.

[14] They are a bit lower because subjects have more strategies at their disposal in the stochastic NDG (and may thus aim at different equilibria than the symmetric ones).



(a) $p = 0.7$ (b) $p = 0.5$ (c) $p = 0.3$

Figure 4: Risk preferences and individual demands

Equilibrium play is uncorrelated to risk aversion. The second observation is that risk preferences are not statistically related to the individual strategy chosen by subjects in our sample. This point is consistent with our first theoretical prediction: despite agents being risk-averse, cautious and dangerous strategies are played when both strategy are more likely to coexist (for $p = 0.7$ and $p = 0.5$).

We observe in Figure 3 an apparent lack of relationship between individual demands and risk preferences. This observation is supported by a random-effect regression with the number of safe choices as the unique explanatory variable (p-value = 0.830).[15] We will confirm this when presenting Result 3: risk aversion does not statistically impact the type of strategy chosen by subjects when integrated as an explanatory variable in a regression. Hence if risk aversion plays a role for determining the existence of both types of equilibria, it does not impact the choice of a dangerous or a cautious strategy when both co-exist.

Result 2: Subjects mainly play the symmetric cautious equilibrium strategy overall, but less so for larger values of p.

The Cautious play is prevalent among equilibrium play. A first set of statistical evidence is provided by Wilcoxon signed rank sum tests: we see that the average cautious group play rate—36.1%— is significantly higher than the dangerous group play rate—13% (p-value of 0.02) over all treatments. Similarly the average symmetric cautious individual play rate—62%—is significantly higher than the symmetric dangerous individual play rate–20% (p-value $<$ 0.01) over all treatments. A paired t-test confirms these results: the average rate of cautious equilibria is significantly higher than the average rate of dangerous

[15] We conditioned also individual demands on those who were more risk-averse and also found no apparent relationship. A similar conclusion is obtained by replacing the number of safe choices from Task 2 with the one coming from the Holt-Laury procedure in task 1 (p-value = 0.299).

equilibria (p-value < 0.01) and the average rate of individual cautious play is significantly higher than the average rate of individual dangerous play (p-value < 0.01).

This effect is stronger within treatment, when p is lower: Wilcoxon signed rank sum tests show that the average symmetric cautious group play rate is not statistically different from the the average symmetric dangerous group play rate in T07 (p-value= 0.115), but is significantly higher when $p = 0.5$ and $p = 0.3$ (p-values = 0.052 and 0.027, respectively). At the individual level, the average symmetric cautious individual play rate is not statistically different from the the average symmetric dangerous individual play rate when in T07 (p-value = 0.345), but is significantly higher when $p = 0.5$ and $p = 0.3$ (p-values = 0.027 and 0.027, respectively).

Coordination on the Cautious play decreases with p. A repeated measure logistic regression confirms that the overall probability to play either symmetric cautious or symmetric dangerous at the individual level significantly differs between T07 and T03 (p-value = 0.02), T05 and T03 (p-value < 0.01) but not between T07 and T05 (p-value= 0.92). Similar conclusions hold when we look only at symmetric dangerous or cautious demands separately. Hence, coordination seemed to be easier when the dangerous equilibrium was less likely to exist (i.e., when the probability of the high value of the resource was lower). An interesting outcome of this coordination failure is the following: we observe that the average observed payoff of agents across all period decreases with the probability p: the average payoff is 4.29 in T07, 4.42 in T05 and 4.94 in T03. Hence, *the higher* the probability of having the high level of resource, *the lower* is the observed average payoff. This observation is supported by a random-effect regression (standard errors clustered at the block level) with only the treatment dummies as explanatory variable. We find that there is no difference in per period average individual payoff between T07 and T05 (p-value = 0.766) while a significant difference appears between T07-T03 and T05-T03 (p-values = 0.013 and 0.291, respectively). The lack of coordination on the (Pareto efficient) cautious strategy is consistent with this finding.[16]

The determinants of the cautious behavior at the individual level (regression analysis). The tendency to adopt cautious behavior is even clearer when we study the determinants of individual demands in more details. We run a random-effect probit regression to evaluate the determinants of the probability of playing the cautious (respectively, dangerous) symmetric demand strategy: the dependent variable takes value 1 if the

[16]The same effect of treatments on payoff is found if we control in addition for "period". Also payoffs are stable across period, in all treatments.

demand by subject i in period t is 6, and 0 otherwise. As independent variables, we include the variable *first belief* ≥ 18, which takes value 1 if the belief in the first period of subject i over the demand of other players is higher than 18, and 0 otherwise[17]. Recall that a belief higher than 18 makes cautious play irrelevant. We add a lag variable, *lag realized value*, which is subject i's threshold realization (resource value of 18 or 24) in Period $t-1$. To test if risk preferences influence behavior, we also include a *risk dummy* which takes value 1 if subject i's switch to lottery B is at $p = 0.7$ or above (i.e. i has an above average risk aversion).[18] Finally, we add dummy variables to capture whether there is a treatment effect (with $T07$ as the reference).

In Table 6, columns (1) and (2) reports regressions at the group level. Column 1 shows that the propensity for groups to play either a dangerous or cautious equilibrium varies significantly across treatments in any given period. The probability for equilibrium play increases by 22.3% in T05, and by 42.5% in T03, compared to T07. In addition, column (2) shows that, if an equilibrium is played, the probability that it be a symmetric equilibrium is also much higher both in T05 and T03 (an increase of 18.5% and 44.4%, respectively). This confirms also that the salience of cautious play, and the focality of symmetric demands is prevalent in T03. Let us now go to Columns (3) and (4) where we study the determinants of cautious and individual play at the individual level. In column (3) we first see that having a high belief in the first period plays a statistically significant (and quantitatively important) role in the likelihood of adopting a cautious play. The threshold realized in the previous period has no impact in playing cautious. Interestingly, the fact that agents are risk-averse has no significant impact on the probability of playing cautiously (in line with our theoretical results). However, in T05 and T03, there is a significant shift in the probability of playing cautiously (p-values < 0.01), of respectively 45.5% and 60.4% compared to T07 –recall that the rate of cautious equilibria in Table 2 was at 5% in T07, while the rate of individual cautious strategies was roughly 30% (110 observations out of 360).

The regression in column (4) of Table 6 mirrors column (3) but with the individual dangerous demand as explanatory variable. As before, risk preferences play no role for the propensity to play the dangerous demand. The regression also confirms the strong treatment effect observed in column (3). The probability of focusing on the dangerous

[17]We consider the belief held by agents only in the first period because we strongly suspect that beliefs in subsequent periods are endogenous (through past play especially). We assume that the individual fixed effects take care of most of the unobserved heterogeneity potentially linking the belief in the first period with the quantity chosen in the first period.

[18]Our results hold for different thresholds specification and for the inclusion of the risk aversion variable in its raw form.

	Equilibrium(1)	**Symmetric**(2)	**Cautious**(3)	**Dangerous**(4)
Constant (T07)	-1.101^{***} (0.192)	-1.181^{***} (0.190)	-1.599^{**} (0.651)	1.175^{*} (0.666)
Period	0.092^{***}(**0.037**) (0.024)	0.069^{***}(**0.026**) (0.024)	0.023 (0.029)	-0.024 (0.038)
First Belief ≥ 18			-0.811^{**}($-$**0.289**) (0.382)	-0.463 (0.497)
Lag realized value			0.304 (0.254)	-0.031 (0.021)
Risk dummy			0.308 (0.262)	0.001 (0.358)
T05	0.568^{***}(**0.223**) (0.170)	0.475^{***}(**0.185**) (0.171)	2.140^{***}(**0.455**) (0.442)	-2.569^{***}($-$**0.151**) (0.594)
T03	1.138^{***}(**0.425**) (0.173)	1.179^{***}(**0.444**) (0.171)	2.763^{***}(**0.604**) (0.446)	-3.039^{***}($-$**0.242**) (0.594)
Observations	360	360	882	882
Log likelihood	-661.889	-648.371	-343.697	-248.379

All regressions are probit regression specification, the constant playing the role of T07. Columns (1) and (2) are standard probit with robust standard errors clustered at the block level. Columns (3) and (4) include in addition an individual specific random effect (random effect probit). Column (1) dependent variable takes value 1 when either a cautious or dangerous equilibrium is played. Column (2) dependent variable takes value 1 when either a symmetric cautious or a symmetric dangerous equilibrium is played. Columns (3) and (4) are at the individual level. Observations for subjects exhibiting multiple switching points in Task 2 are excluded from the regressions in (3) and (4). Explanatory variables are explained in the text prior to the regression results. In each of columns (1), (2) and (3) numbers in parentheses are the predicted probabilities. Asterisks above coefficients indicate the level of significance of the coefficients in the regressions (* means significance at the 10% level, ** significance at the 5% level and *** significance at the 1% level).

Table 5: Equilibrium Play

equilibrium strategy strongly differs across treatments. Hence, dangerous play at the individual level is influenced by the probability p of obtaining the high value: as p goes down, agents focus less and less on the dangerous strategy (and more and more on the cautious demand).

Result 3: Coordination on any equilibria becomes more difficult when co-existence of equilibria is more likely. The main observation here is that agents' actions are less and less in line with an equilibrium when the co-existence of equilibria becomes more likely[19]. An important aspect of equilibrium versus non-equilibrium behavior in the stochastic NDG is the extent to which subjects fail to precisely coordinate on one of the two of the symmetric dangerous and cautious demand. Given the anonymity

[19] As mentioned above this trend should disappear for very low value of p, when the dangerous equilibrium becomes very unlikely, and for very high value of p, when the cautious equilibrium disappear. We ran a pilot treatment with $p = 1$ and—as predicted—we observed a high rate of equilibria, close the rate we observe when $p = 0.3$. The results are available upon request.

conditions in which the experiment takes place, and despite the possible learning at play because of repeated interactions, having symmetric (equilibrium) demand profiles seems focal. This is however not informative regarding the extent to which subjects may fail to fully coordinate on one of the two of the symmetric dangerous and cautious demand profiles when they coexist. Table 7 shows some evidence based on probit regressions with different measures of coordination failures as explanatory variables.

Coordination failures Let us define a *coordination failure* as an instance in which subjects in a group tried to coordinate on one of the two symmetric equilibrium demand profiles, but fail. We introduce three different measures of such failures. In column (1), we define *low coordination failure* as those groups in which at least one subject chose one of the two symmetric equilibrium demands—Column (2) is for the case when there are at least two subjects who chose symmetric equilibrium demands. A *pure coordination failure* (Column (3)) is a situation in which all subjects in a group each demanded either 6 or 8 but the sum of their demands didn't sum to either 18 or 24. We see that coordination failures decrease as p goes down, hence when the dangerous becomes more and more unlikely. The predicted probability to witness a pure coordination failure significantly decreases from 26% in T07 to 9% in T03 (p-values < 0.01). The predicted difference between T05 and T03 is however not significant. The observation that coordination failures decrease when co-existence is less likely carries over to the alternative definitions used for the explanatory dummy in column (1) and (2). This, along with our first observation that symmetric Nash equilibrium rates are negatively correlated with p, indicates that subjects find it easier to play cautious when p goes down. The theoretical results indicate that this is likely due to a lower chance of coexisting equilibrium (the cautious equilibrium becoming more tempting). Another interpretation could be that subjects become more prudent when the high value h becomes less likely, and revert to cautious demands. This possibility is reinforced by our next observation.

Dangerous play and overshooting Let us briefly investigate collective claims beyond either the high or low value of the resource. We say (i) that a group is *overshooting* in a given period if its (group) demand exceeds 24 –recall that subjects in the group each gets 0 in this case–, and (ii) that a group demand is in the *dangerous zone* if it exceeds 18 –in such a case, with probability $(1 - p)$ subjects in the group each gets 0. Regarding overshooting we notice interesting differences across treatments. At the group level, rates of overshooting are rather low, 8.3% (T07) and 11.6% (T05) with a drop at 0.08% in T03.

	Low failure(1)		**Medium failure**(2)		**Pure failure**(3)	
T07	0.680^{***} (0.245)	(0.716^{***})	0.387^{**} (0.176)	(0.625^{***})	-0.671^{**} (0.216)	(0.266^{***})
T05	-0.573^{*} (0.350)	(0.50^{***})	-0.572^{**} (0.282)	(0.40^{***})	-0.527^{**} (0.252)	(0.125^{***})
T03	-1.098^{***} (0.359)	(0.30^{***})	-0.892^{***} (-0.283)	(0.283^{***})	-0.709^{***} (0.281)	(0.035^{***})

All regressions are computed using all observations at the groups level (360 observations). Standard errors for each variable are shown below each coefficient and are constructed from a probit regression specification with robust standard errors clustered at the block level. Each regression includes only the treatment dummies (the constant playing the role of T07) and "period" as explanatory variables. The non-significant variable "period" is not shown. Dependent variables are dummies which takes value 1 if at least one subject's demand is 6 or 8 in the group (column (1)), or takes value 1 if at least two subjects' demands are either 6 or 8 in the group (column (2)), or takes value 1 if all subjects' demands are either 6 or 8 in the group but the group demand is neither 18 nor 24. In each of columns (1), (2) and (3) numbers in parentheses next to the coefficients are the predicted probabilities obtained from the probit regressions. Asterisks above coefficients indicate the level of significance of the coefficients in the regressions (* means significance at the 10% level, ** significance at the 5% level and *** significance at the 1% level).

Table 6: Coordination Failures

Table 8 shows estimations based on probit regressions with explanatory variables overshooting and dangerous zone coded as dummies. Column (1) shows that the probability of overshooting is not significantly different between T07 and T05 –predicted probability at 8% in T07 and 11% in T03– but there is a drop to a less than 1% probability in T03 –this predicted probability is not significant but the effect on the latent propensity to overshoot is negative and significant in T03. In conjunction with our discussion of Table 7, it is important to notice that subjects behave significantly more cautiously as p goes down. Indeed, using our definition *dangerous zone*, column 2 of Table 8 shows significant differences across treatments. The predicted probability for a group to be in the dangerous zone in T07 is 90%. There is a significant decrease (p-value < 0.01) in the probability to reach the dangerous zone for both T05 and T03, respectively a decrease to a probability of 58% and 22% compared to T07 –over the pooled data, the predicted probability to be in the dangerous zone is at 55% (p-value < 0.01).[20]

6 Concluding remarks

We analyzed the behavior of rational agents sharing a non-excludable good that disappear beyond an uncertain threshold. We modeled this situation as a version of the well-known Nash Demand Game in which the amount to be split follows a discrete probability distribu-

[20]Different estimation methods lead to similar results, e.g. random effect probit or repeated measures logistic. We choose a simple probit estimation method because predicted probabilities and marginal effects are easily computed.

	Overshoot(1)	**Dangerous zone**(2)	**Test T0X=T07** (Dangerous zone)(3)
T07	-1.382^{***} (0.082) (0.341)	1.330^{***} (0.908^{***}) (0.259)	
T05	0.191 (0.116^{**}) (0.451)	-1.120^{***} (0.583^{***}) (0.345)	0.52
T03	-1.010^{**} (0.008) (0.485)	-2.085^{***} (0.225^{***}) (0.294)	0.33 (0.20)

The coefficients and statistical tests are calculated using all observations at the group level (360 observations). Standard errors for each variable are shown below each coefficient and are constructed from a probit regression specification with robust standard errors clustered at the block level. Each regression includes only the treatment dummies (the constant playing the role of T07) and "period" as explanatory variables. The non-significant variable "period" is not shown. Explanatory variables are dummies which takes value 1 if the group demand is beyond 24 (column (1)), or takes value 1 if the group demand is above 18 (column (2)). In each of columns (1) and (2), numbers in parentheses are the predicted probabilities obtained from the probit regressions –numbers in parentheses in row T07 for columns (1) and (2) are the predicted probability for a group demand to be respectively in overshoot or only in the dangerous zone. Column (3) shows the p-values of a Mann-Whitney non-parametric test with block average group demand clustered over demands higher than 18 as the unit of observation (6 observations per treatment). In the T03 row, the number in parentheses for the last indicates the p-value of the Mann-Whitney test between T05 and T03. Asterisks above coefficients indicate the level of significance of the coefficients in the regressions (* means significance at the 10% level, ** significance at the 5% level and *** significance at the 1% level).

Table 7: Determinants of the dangerous zones

tion. This brought two new theoretical insights. First, strategic interaction can have much more impact on the outcome than individual characteristics: irrespective of the agents' degree of risk aversion, "cautious" equilibria—where agents together behave as if the lowest (and safest) threshold were certain—were found to coexist with "dangerous" equilibria —where the agents' request might lead to a breakdown—and even "dreadful" equilibria, where so much is claimed collectively that no single player's actions can prevent the collapse. Second, cautious equilibria were shown to have robust properties: they are strong and dominates many dangerous equilibria.

Our experimental results mostly confirm these results. First, both types of strategies, cautious and dangerous, coexist in the experiment even if all subjects are risk averse. Our findings confirm our theoretical predictions that the (Pareto-dominant) cautious equilibria are predominantly played at the individual level. However, coordination failures abound but are decreasing in the likelihood of the high value of the resource. It is only when this likelihood becomes low enough that cautious behavior translates in the aggregate to high rates of cautious equilibria.

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A Appendix: Extensions

The game considered so far had only two thresholds. This section will now successively consider a situation with multiple thresholds and one with a continuum of possible thresholds randomly spread according to a multimodal probability distribution. The former case could stem from greater disagreement among experts, the latter from acknowledging measurement errors and aggregating various interval or probabilistic estimates (instead of point estimates) of thresholds.

A.1 Multiple thresholds

Suppose the predicted thresholds now belong to a finite set, $A = \{a_1, ..., a_m\} \subset \mathbb{R}_+$. The capacity is then either $a_1 > 0$ with probability p_1, $a_2 > a_1$ with probability p_2,..., or $a_m > a_{m-1}$ with probability $p_m = 1 - p_1 - p_2 - ... - p_{m-1}$.

As before, let each agent $i = 1, ...n$ claim an amount $x_i \geq 0$. If all claims add up to less than or exactly the actual threshold, agent i's demand, x_i, is met. On the other hand, if the sum, X, of all demands exceeds the true capacity, every agent gets 0. Let $\bar{p}_i = \sum_{j=i}^{m} p_j$; agent i's expected payoff is given by

$$v_i(x_i, X_{-i}) = u(x_i)\mathbb{I}(X \leq a_1) \ + \ ... \ + \ \bar{p}_m u_i(x_i)\mathbb{I}(a_{m-1} < X \leq a_m) \tag{9}$$

Proceeding as we did in Section 3, let $\bar{X}_i^j$ with $i \in N$ and $j = 1, ..., m-1$ denote the cut-off values defined as:

$$\begin{cases} \bar{p}_j u_i(a_j - X_{-i}) > \bar{p}_{j+1} u_i(a_{j+1} - X_{-i}) & \text{if } X_{-i} < \bar{X}_i^j \\ \bar{p}_j u_i(a_j - X_{-i}) < \bar{p}_{j+1} u_i(a_{j+1} - X_{-i}) & \text{if } X_{-i} > \bar{X}_i^j \end{cases} \tag{10}$$

The following statement is a generalization of Lemma 1.

Lemma 2. *The cut-offs of each agent i follow the natural order:*

$$0 = \bar{X}_i^0 \leq \bar{X}_i^1 \leq \bar{X}_i^2 \leq ... \leq \bar{X}_i^{m-1} \leq \bar{X}_i^m = a_m.$$

Hence, demanding $x_i = a - X_{-i}$ is the best response to $X_{-i} \in [\bar{X}_i^{k-1}, \bar{X}_i^k]$.

Proof. See the Appendix. □

Let us now call *cautious* a Nash equilibrium strategy profile x^* where $X^* = \sum_{i=1}^{n} x_i^* = a_1$, *h-dangerous* a Nash equilibrium in which $X^* = a_h$, and *dreadful* a Nash equilibrium where $X^* > a_m$. Conditions that guarantee the existence of these equilibria are given below.

Proposition 4. *The game always admits at least one non-dreadful equilibrium. Furthermore,*

1) A cautious equilibrium exists if and only if $\sum_{i\in N}\bar{X}_i^1 \geq (n-1)a_1$*;*

2) For any $h \in \{2,...,m\}$*, an* $h-$*dangerous equilibrium exists if and only if*

$$\sum_{i\in N}\bar{X}_i^{k-1} \leq (n-1)a_k \leq \sum_{i\in N}\bar{X}_i^k$$

This proposition implies that cautious and all h-dangerous equilibria may coexist. The underlying argument matches the one used in the proof of Theorem 1.

The possibility of group deviations would again make dreadful equilibria and certain dangerous equilibria untenable. The following statements are straightforward extensions of Theorem 2 and Proposition 1.

Proposition 5. *Cautious Nash equilibria are strong; dreadful Nash equilibria are not.*

Proposition 6. *Let a strategy profile* x *be an* h*-dangerous equilibrium. If there is an* h'*-dangerous equilibrium* x'*,* $h' < h$*, such that for a subgroup* $T \subseteq N$*,*

$$\begin{aligned} x_i' &= x_i - \alpha_i \qquad \text{for all } i \in T, \text{ and} \\ x_i' &= x_i \qquad \text{for all } i \notin T \end{aligned}$$

with $\alpha_i \geq 0$ *for all* $i \in T$ *and* $\sum_i \alpha_i = 1 - a_{h'}$ *, then* x *is not coalition-proof.*

More clearly than its counterpart in section 3, the latter proposition conveys a notion of gradualism (which may matter, for instance, in international climate policy negotiations). The h'-equilibrium that a group of agents would prefer to the riskier h-equilibrium may not itself be coalition-proof. In this case, one can imagine that another deviation to an even safer h''-equilibrium might occur, and so on, until a cautious equilibrium is reached.

We shall now show that these results do not depend (qualitatively, at least) on having the threshold take only a finite number of possible values.

A.2 Continuous (multimodal) distributions of thresholds

Consider now a situation where the threshold, r, is located according to a common-knowledge distribution function F, with density f, such that $F(0) = 0$. Focusing on our interpretation of different experts' opinions, we view F as an aggregate of various interval or probabilistic estimates of the threshold and assume it is multimodal: it is the (exogenous) aggregation of each experts' prediction. Each mode might represent an experts' (unimodal) belief over the threshold, while the probability weight attributed to each distribution is exogenously given.

Again, let each agent $i = 1, ...n$ make a claim $x_i \geq 0$. If the sum X of individual demands amounts to no more than r, all requests x_i are satisfied; otherwise, everybody gets 0. The probability of not exceeding the threshold being equal to $1 - F(X)$, agent i's expected payoff is then

$$v_i(x_i, X_{-i}) = u_i(x_i)(1 - F(x_i + X_{-i})) \tag{11}$$

The first-order necessary condition for maximizing agent i's payoff is now given by

$$\frac{u_i'(x_i)}{u_i(x_i)} = \frac{f(x_i + X_{-i})}{1 - F(x_i + X_{-i})} \tag{12}$$

The left-hand side of this expression increases with x_i. The right-hand side is the so-called hazard rate. The literature on mechanism design (see, e.g., Bulow and Roberts 1989; Levin 1997) usually assumes the latter to be monotonically decreasing. Here, multimodality may cause it to be non-monotonic, since between two sufficiently far off predictions the density f will first decline and then grow sharply. This means there might actually be several local maxima.

A Nash equilibrium requires of course that each player be at a *global* maximum, given the other players' claim. Such an outcome will be called *cautious* (*dangerous*) when total demand is at the lowest (highest) level. It turns out that *both types of equilibria may coexist*, even in this continuous framework, as the following examples illustrate. A notable difference with the discrete case is that there can be only one Nash equilibrium of a kind.

Example 3. Suppose there are three agents with identical utility function $u_i(x_i) = \sqrt{x_i}$, $i = 1, 2, 3$. Let the distribution function of the threshold, F, be the weighted sum of two different expert assessments: the first one is a normal distribution with mean equal to 8 and variance equal to 1, the second is also a normal distribution with mean 18 and variance 1. The respective weights put on the former and the latter are 0.9 and 0.1. Two symmetric Nash equilibria coexist in this case: they are the symmetric solutions to Expression (12)[21]. In one equilibrium—the cautious one—each agent claims an amount 2.29 of natural capital. In the other—the dangerous equilibrium—each agent requests 5.42. One checks that these demand levels are indeed global payoff maximizers.

[21]The first-order function $\frac{u_i'}{u_i} - \frac{f(3x)}{1-F(3x)}$ actually has four roots (Figure 2(b)), but only the ones achieved from above yield local maxima (the other two correspond to local minima).

As the next proposition shows, finally, the cautious equilibrium in this continuous setting is still a strong Nash equilibrium; it dominates any dangerous equilibrium in which every agent makes a bigger claim.

Proposition 7. *The cautious equilibrium is a strong Nash equilibrium. It Pareto-dominates any dangerous equilibrium in which everyone asks for more.*

Proof. The argument for the first part mimics that for Theorem 2. Denote by x the cautious equilibrium of the game. Consider another equilibrium, x', to be the result of a profitable deviation by coalition $T \subseteq N$. Clearly $|T| \geq 2$, or x would not be a Nash equilibrium of the game. Also, it must be that $X' \neq X$. Suppose $X' > X$, and consider an agent $j \in T$ such that $X^{'}_{-j} > X_{-j}$. Such an agent exist because $|T| \geq 2$. Denote by $x^*_j(X'_{-j})$ agent j's best response to all other agents collectively demanding X'_{-j}. By the monotonicity of u_j, it must be that

$$\begin{aligned} v_j(x'_j, X'_{-j}) &\leq v_j(x^*_j(X'_{-j}), X'_{-j}) \\ &= u_j(x^*_j(X'_{-j})) \times (1 - F(x^*_j(X'_{-j}) + X'_{-j})) \\ &< u_j(x^*_j(X'_{-j}) + X'_{-j} - X_{-j}) \times (1 - F(x^*_j(X'_{-j}) + X'_{-j})) \\ &= v_j(x^*_j(X'_{-j}) + X'_{-j} - X_{-j}, X_{-j}) \\ &\leq v_j(x_j, X_{-j}) \end{aligned}$$

with the last inequality coming from the fact that x is a Nash equilibrium of the game. A cautious equilibrium being a Nash equilibrium with the lowest total demand by definition, the case $X' < X$ cannot happen.

To prove the second part, denote by x the cautious equilibrium of the game and by x' a dangerous equilibrium such that $X'_{-i} \geq X_{-i}$ for all $i \in N$. From the definition of an equilibrium, we know that for all i

$$v_i(x_i, X_{-i}) \geq v_i(x'_i, X_{-i}). \tag{13}$$

Furthermore, v_i is non-increasing in its second argument, because a larger value implies smaller odds of obtaining a positive payoff. Therefore,

$$v_i(x'_i, X_{-i}) \geq v_i(x'_i, X'_{-i}). \tag{14}$$

Combining the last two expressions hands the result. □

B Appendix: Instructions (for online publication only)

We attach below the instructions used in the experiment –all parts compiled in a single document. Part 1 refers to T07. Recall that subjects knew that there would be three parts in the experiment. However, they had no knowledge of the content of Part 2 while playing Part 1.

v.1

General Instructions

Welcome to this economic experiment. In the experiment you and other participants will make decisions. Next to the fee of **5 CHF** for showing up in time, you can earn money in the experiment. How much you earn depends on your own decisions and the decisions of other participants. At the end of the experiment the show-up fee and the earnings from the different parts will be added up and confidentially paid out to you.

The experiment consists of three different parts that are all independent of one another. For each part you will receive specific instructions. These instructions will explain how you make decisions and how your decisions and the decisions of other participants influence your earnings. Therefore, it is important that you read the instructions carefully.

From now on you are **not allowed to communicate in any other way than specified in the instructions**. Please obey to this rule because otherwise we have to exclude you from the experiment and all earnings you have made will be lost. Please also do not ask questions aloud. If you have a question raise your hand. A member of the experimenter team will come to you and answer your question in private.

Specific instructions – Part 1

In this part of the experiment you can earn money with the decisions you make. How much you earn depends on your own decisions, the decisions of other participants as well as random events. We will not speak of CHF during the experiment, but rather of experimental dollars. All you earnings will first be calculated in points. At the end of the experiment the total amount of points you earned in this part will be converted to Euro at the following rate:

1 point = 0.8 CHF

At the beginning of this part of the experiment participants will be randomly divided into two **blocks of six**. **You will not get to know the identity of the people in your block**, neither during nor after the experiment. **The other block members will also not get to know your identity**. These two blocked stay the same throughout Part 1. Next, within each of the two block, **two groups of three** will be formed. **You will not get to know the identity of the other group members**, neither during nor after the experiment. **The other group members will also not get to know your identity**. A decision situation (explained below) will be repeated for 10 periods. Each period, new groups of three will be randomly formed within each block.

The decision situation:

You will be the member of a **group** of **3 people**. Available to each group is a sum of experimental dollars. However the sum available can take two different values. With probability 0.7, the amount of experimental dollars available to the group is 24. With probability 0.3, the amount of experimental dollars available to the group is 18. Each group member has to privately decide on the share of the amount of experimental dollars he/she will demand. The share demanded must be an integer between 0 and 24. At the time of deciding on the share demanded, the amount of experimental dollars available to the group (either 18 or 24) **is not known**. **The realized amount available will be determined randomly according to the above probabilities by the computer once all decisions have been made**.

Once each group member has made his/her decision, the computer randomly determines whether the amount of experimental dollar available is 24 or 18. With probability 0.7, the amount available is 24. With probability 0.3, the amount available is 18.

The way earnings are determined is as follows. If the sum of the demands in the group is less than or equal to the amount of experimental dollar available, then each group member receives the share he asked for, and the surplus of experimental dollars (if any) is thrown away. However if the sum of demands exceeds the amount of experimental dollars available, then each group members receives 0 (the amount of experimental dollars available is thrown away).

Your earnings from your demand decision in a given round are thus equal to EITHER

1) **Your demand if the sum of demands in your group are less than or equal to the realized amount of experimental dollars available (as determined by the computer)**
2) **0 if the sum of demands exceeds the realized amount of experimental dollars available (as determined by the computer)**

CONTROL QUESTIONS- decision situation:

Please answer the following control questions. These questions are arbitrary examples of what could happen in the experiment. They will help you to gain an understanding of the calculation of your earnings. Your earnings vary with your own decision and with the decisions of the other group members.

Please answer all the questions and write down your calculations.

1. Each of the group members (including you) demands 24.

What will ***your earnings*** be? ___________

What will the ***earnings of each of the other group members*** be? ___________

2. You demand 20 and each of the other group member demand 2.

a) What will ***your earnings*** be, if the realized amount of experimental dollars (as determined by the computer) is 24?

Your total earnings ___________

b) What will ***your earnings*** be, if the realized amount of experimental dollars (as determined by the computer) is 18?

Your total earnings ___________

3. You demand 4 and each of the other group member demand 6.

What will ***your earnings*** be? ___________

What will the ***earnings of each of the other group members*** be? ___________

4. Each group member (including you) demands 7.

a) What will ***your earnings*** be, if the realized amount of experimental dollars (as determined by the computer) is 24?

Your total earnings ___________

b) What will ***your earnings*** be, if the realized amount of experimental dollars (as determined by the computer) is 18?

Your total earnings ___________

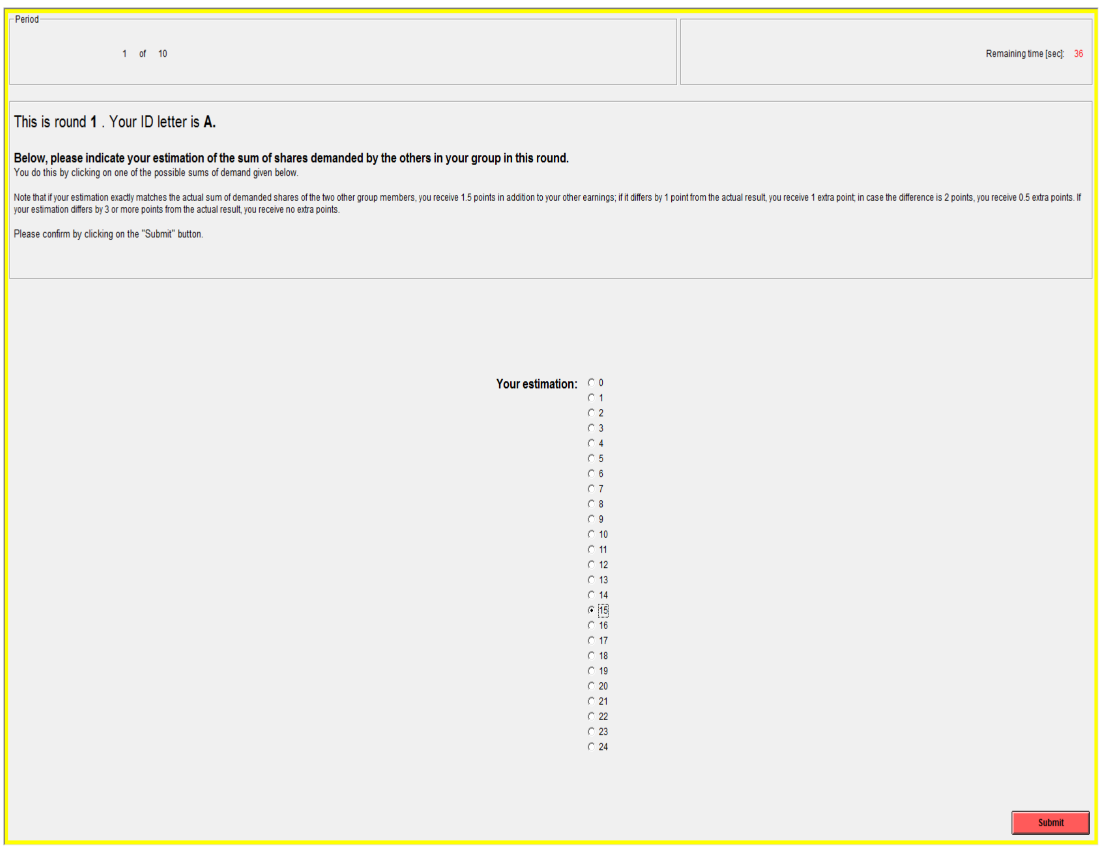
ONCE YOU ARE DONE FILLING THE CONTROL QUESTIONS, PLEASE RAISE YOUR HAND AND ONE OF THE EXPERIMENTER WILL COME TO CHECK YOUR ANSWERS.

v.1

In this part of the experiment you will be engaged in the decision situation for **10** successive **periods**. In each period you and the other two group members will be randomly rematched into new groups of three within the block you belong to.

In each period you and the other group members have to make a **share demand decision** but also an **estimation** of the actual sum of demands of the other 2 group members. When you make your decisions you do not know the decisions of the other group members nor do the other group members know your decisions. At the end of a period you will be informed about the demands in your group in that period.

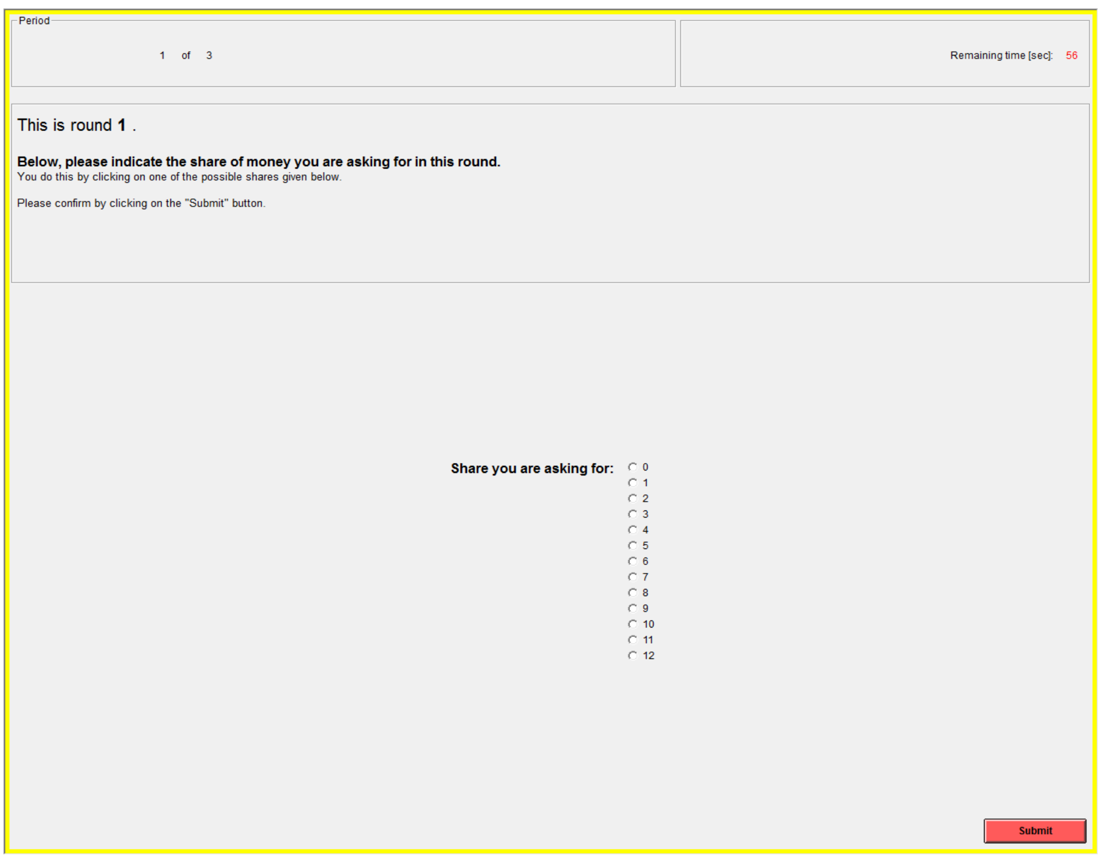
In each period you will make your **estimation** and **share demand** on a screen as shown below:



- If your estimate is **exactly right** (that is, if your estimate **exactly** matches the rounded actual sum of demands of the other group members), you will receive **1.5 points** extra to your other earnings from the experiment.
- If your estimate **deviates by 1 point** from the actual result, you will receive **1 points** extra.
- If your estimate **deviates by 2 points** from the actual result, you will receive **0.5 point** extra

If your estimate **deviates by 3 or more points** from the correct result, you will receive **no points**

Your next decision is the Demand decision.



After the 10 periods of this part are over, Part 1 ends. There will be two additional and independent parts for this experiment.

From Part 1, 3 out of the 10 periods will be chosen randomly by the computer and paid out, as part of your total earnings in the experiment. This is the end of the instructions for Part 1. If you have a question please raise your hand.

Specific instructions – Part 2

In this part and in the next one (Part 3) of the experiment you can earn money with the decisions you make. How much you earn depends on your own decisions as well as random events. A word of caution though. You will have to make several choices, but only one of them will be payoff-relevant. So you should take each decision seriously. A second word of caution: only Part 2 or Part 3 will be payment-relevant. The computer will randomly choose (each with probability 0.5) either Part 2 or Part 3 to be payment-relevant.

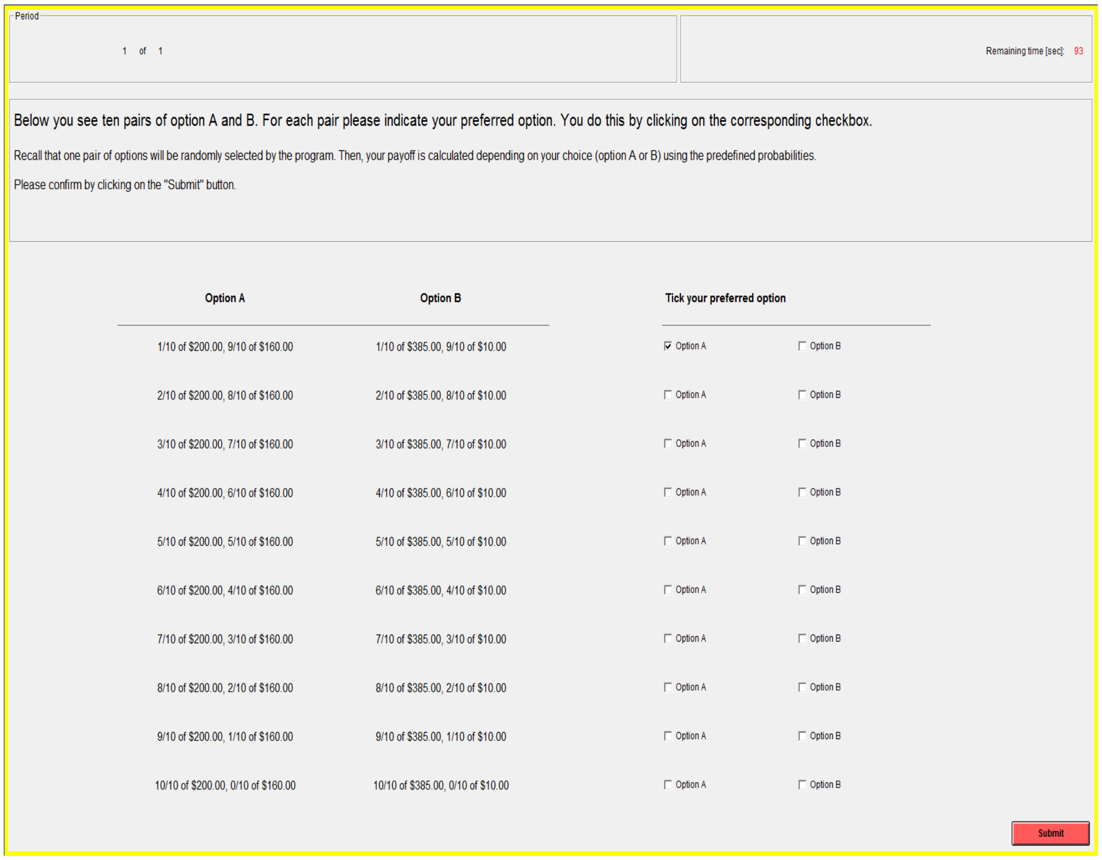
We will not speak of CHF during the experiment, but rather of experimental dollars. All you earnings will first be calculated in experimental dollars. At the end of the experiment the total amount of experimental dollars you earned in this part will be converted to CHF at the following rate:

1 experimental dollar = 0.05 CHF

We now describe how this part of the experiment proceeds. First you will be introduced to the basic decision situation, thereafter you will learn more specifically how the experiment is conducted. You will also be asked some control questions that will help you to understand the decision situation.

The decision situation:
You will be faced with 10 decisions. Each decision is a paired choice between two gambles (termed Option A and Option B). For each pair, you will have to state a choice between Option A and Option B. Once all the participants have decided which option they prefer for each of the ten decisions, the computer will randomly determine which of Decision 1, 2,…., or 10 will be payoff relevant. Once the payoff relevant decision is selected, the computer will choose randomly one more time to determine the realization you have chosen. How things work in practice will be made clear with the help of an example.

The way the 10-decisions situation will look like on your screen is shown on the next page.



Period

1 of 1

Remaining time [sec]: 93

Below you see ten pairs of option A and B. For each pair please indicate your preferred option. You do this by clicking on the corresponding checkbox.

Recall that one pair of options will be randomly selected by the program. Then, your payoff is calculated depending on your choice (option A or B) using the predefined probabilities.

Please confirm by clicking on the "Submit" button.

Option A	Option B	Tick your preferred option	
1/10 of $200.00, 9/10 of $160.00	1/10 of $385.00, 9/10 of $10.00	☑ Option A	☐ Option B
2/10 of $200.00, 8/10 of $160.00	2/10 of $385.00, 8/10 of $10.00	☐ Option A	☐ Option B
3/10 of $200.00, 7/10 of $160.00	3/10 of $385.00, 7/10 of $10.00	☐ Option A	☐ Option B
4/10 of $200.00, 6/10 of $160.00	4/10 of $385.00, 6/10 of $10.00	☐ Option A	☐ Option B
5/10 of $200.00, 5/10 of $160.00	5/10 of $385.00, 5/10 of $10.00	☐ Option A	☐ Option B
6/10 of $200.00, 4/10 of $160.00	6/10 of $385.00, 4/10 of $10.00	☐ Option A	☐ Option B
7/10 of $200.00, 3/10 of $160.00	7/10 of $385.00, 3/10 of $10.00	☐ Option A	☐ Option B
8/10 of $200.00, 2/10 of $160.00	8/10 of $385.00, 2/10 of $10.00	☐ Option A	☐ Option B
9/10 of $200.00, 1/10 of $160.00	9/10 of $385.00, 1/10 of $10.00	☐ Option A	☐ Option B
10/10 of $200.00, 0/10 of $160.00	10/10 of $385.00, 0/10 of $10.00	☐ Option A	☐ Option B

Submit

Remember that the computer randomly determines both which of Decision 1, 2, 3,…, 10 is payoff-relevant, and the realization (i.e. money) for the option you chose for this decision.

Look at Decision 1 at the top of the table. Suppose Decision 1 is selected by the computer. You see in the table that Option A pays 200$ with probability 1/10 and 160$ with probability 9/10. Option B pays 385$ with probability 1/10 and 10$ with probability 9/10. This means that Option A pays 200$ if the second number selected by the computer is 1, and 160$ if number selected is either 2, 3, 4,…, or 10.

The other Decisions are similar except that as you move down the table, the chances of the higher payoff for each option increase. In fact, notice that if Decision 10 is selected as the payoff-relevant decision by the computer, then things stop since each option pays the highest payoff for sure (probability 10/10=1).

To summarize, you will make ten choices: for each decision row you have to choose between Option A and Option B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. When everyone is done, the computer randomly chooses which decision is payoff-relevant and which realization is relevant.

Your earnings in experimental dollars will then be determined and stored until the end of the experiment. Recall that out of Parts 2 and 3, your earnings from only one of these two parts will be paid out to you (in addition to your earnings from Part 1).

Specific instructions – Part 3

In this part (as in Part 2) of the experiment you can earn money with the decisions you make. How much you earn depends on your own decisions as well as random events. A word of caution though. You will have to make several choices, but only one of them will be payoff-relevant. So you should take each decision seriously. A second word of caution: only Part 2 or Part 3 will be payment-relevant. The computer will randomly choose (each with probability 0.5) either Part 2 or Part 3 to be payment-relevant.

We will not speak of CHF during the experiment, but rather of experimental dollars. All you earnings will first be calculated in experimental dollars. At the end of the experiment the total amount of experimental dollars you earned in this part will be converted to CHF at the following rate:

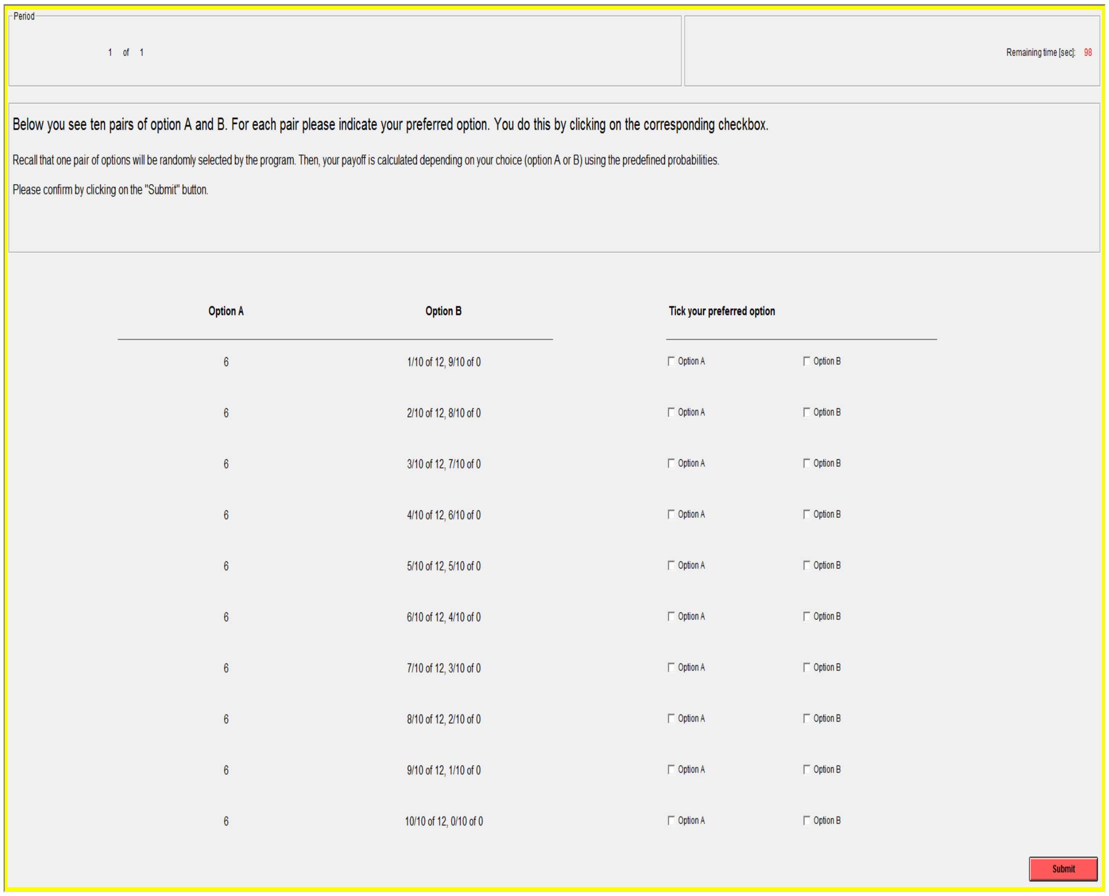
1 experimental dollar = 1 CHF

We now describe how this part of the experiment proceeds. First you will be introduced to the basic decision situation, thereafter you will learn more specifically how the experiment is conducted. You will also be asked some control questions that will help you to understand the decision situation.

The decision situation:

You will be faced with 10 decisions. Each decision is a paired choice between two gambles (termed Option A and Option B). For each pair, you will have to state a choice between Option A and Option B. Once all the participants have decided which option they prefer for each of the ten decisions, the computer will randomly determine which of Decision 1, 2,…., or 10 will be payoff relevant. Once the payoff relevant decision is selected, the computer will choose randomly one more time to determine the realization you have chosen. How things work in practice will be made clear with the help of an example.

The way the 10-decisions situation will look like on your screen is shown on the next page.


Period

1 of 1

Remaining time [sec]: 98

Below you see ten pairs of option A and B. For each pair please indicate your preferred option. You do this by clicking on the corresponding checkbox.

Recall that one pair of options will be randomly selected by the program. Then, your payoff is calculated depending on your choice (option A or B) using the predefined probabilities.

Please confirm by clicking on the "Submit" button.

Option A	Option B	Tick your preferred option	
6	1/10 of 12, 9/10 of 0	Option A	Option B
6	2/10 of 12, 8/10 of 0	Option A	Option B
6	3/10 of 12, 7/10 of 0	Option A	Option B
6	4/10 of 12, 6/10 of 0	Option A	Option B
6	5/10 of 12, 5/10 of 0	Option A	Option B
6	6/10 of 12, 4/10 of 0	Option A	Option B
6	7/10 of 12, 3/10 of 0	Option A	Option B
6	8/10 of 12, 2/10 of 0	Option A	Option B
6	9/10 of 12, 1/10 of 0	Option A	Option B
6	10/10 of 12, 0/10 of 0	Option A	Option B

Submit

Remember that the computer randomly determines both which of Decision 1, 2, 3,…, 10 is payoff-relevant, and the realization (i.e. money) for the option you chose for this decision.

Look at Decision 1 at the top of the table. Suppose Decision 1 is selected by the computer. You see in the table that Option A pays 6$ with probability 1. Option B pays 12$ with probability 1/10 and 0$ with probability 9/10. This means that Option A pays 6$ for sure. Option B pays 12$ if the second number selected by the computer is 1, and 0$ if the second number selected is either 2, 3, 4,…, or 10.

For each of the other decision, Option A remains the same. Option B changes. As you move down the table, the chances of the higher payoff attached to option B increases. In fact, notice that if Decision 10 is selected as the payoff-relevant decision by the computer, then things stop since option B pays the highest payoff (12) for sure (probability 10/10=1).

To summarize, you will make ten choices: for each decision row you have to choose between Option A and Option B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. When everyone is done, the computer randomly chooses which decision is payoff-relevant and which realization is relevant.

Your earnings in experimental dollars will then be determined and stored until the end of the experiment. Recall that out of Parts 2 and 3, your earnings from only one of these two parts will be paid out to you (in addition to your earnings from Part 1).