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Collective Dangerous Behavior: Theory and Evidence on Risk-Taking

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Abstract

It is commonly found that uncertainty helps discipline economic agents in strategic contexts. Using a stochastic variant of the Nash Demand Game, we show that the presence of uncertainty may have a dramatically opposite effect. *Cautious* (efficient) and *dangerous* (inefficient) equilibria may co-exist regardless of agents' risk preferences.

We report experimental evidence on these predictions. We find that a risk-taking society may emerge from the decentralized actions of risk-averse individuals. Subjects predominantly play symmetric dangerous equilibria, even when all agents are risk averse. An important driver for this result is the pessimistic beliefs of subjects regarding others' claims.

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1 Introduction

It is commonly found that the presence of uncertainty helps discipline economic agents in strategic contexts where incentives would otherwise induce inefficient behavior. For instance, using different frameworks, Sandler and Sterbenz (1990), Eso and White (2003), White (2004) or Bramoullé and Treich (2009) show that risk-averse agents tend to adapt their behavior when facing uncertainty in a way that increases welfare. Hence, and somewhat counterintuitively, uncertainty can be perceived as a "good" thing even when all agents are risk averse.

By contrast, we show that the presence of uncertainty in a Nash Demand Game framework may have a dramatically opposite effect: strategic interactions may drive agents to behave as if they were overly optimistic about the uncertain outcome and lead to the existence of inefficient equilibria −*dangerous equilibria*. Surprisingly, dangerous equilibria may exist even when all agents are risk averse, and may coexist with *cautious equilibria*, where all agents behave as if the pessimistic outcome were certain. In other words, a risk-taking society may emerge from the decentralized actions of risk-averse individuals. We then develop an experimental setting to assess the severity of the coordination problem in the lab and confirm that agents tend to adopt a collective dangerous behavior despite their individual risk aversion.

In the first part of the paper, we amend the well-known Nash Demand Game (Nash 1950; Malueg 2009) by supposing that symmetrically informed players are splitting an uncertain amount of a resource following a discrete probability distribution. This setting seems to capture a number of stylized situations: in climate change negotiations, for instance, parties normally focus on a finite number of collective targets, such as 550 parts per million (ppm) of carbon dioxide (CO_2)-equivalent - a politically sensible objective that many think is unlikely to prevent major environmental disruptions, 450 ppm - which may limit global warming to a manageable level (thought to be 2°C), or 350 ppm - which some scientists and vulnerable countries regard as the upper bound on emissions that guarantees the preservation of the present biosphere [1]

In sharp contrast with results in the previous literature, uncertainty here does not

[1]Other examples abound, for example among public health applications are epidemiological concerns: some diseases become epidemic past a threshold of infected people, with uncertainty about the threshold. If the threshold rate of infection is reached, the resulting infectious agents can spread quickly through a worldwide contiguous, highly mobile, human population with few barriers to transmission. Similarly, certain viruses become resistant to antibiotics past an (uncertain) level of collective use of a specific drug. For more information about these issues, and for more examples, we refer the reader to Laurent-Lucchetti et al (2013).

always lead agents to be more careful, even when all agents are risk averse: cautious equilibria coexist with dangerous equilibria and even with *dreadful equilibria*, where agents collectively claim so much of the resource that no unilateral deviation by one agent can stop its exhaustion.[2] We conclude the theory part by showing that any cautious equilibrium is efficient and Pareto-dominates all dangerous equilibria that can be reached from it while increasing every agent's claim.

We then develop an experimental setting to assess the severity of the coordination problem in the lab. Subjects play a simple stochastic Nash Demand Game where the total amount to be divided can either be "high" or "low", with known probabilities. We also elicit the risk preferences of players using the well known procedure developed in Holt and Laury (2002). Our experimental results confirm the theoretical findings: subjects coordinate on the symmetric "dangerous" equilibrium, where they collectively claim the high amount of resource, even if the probability of such a state of the world occurring is small and even if everyone involved is risk averse. Moreover, we find that when Pareto-dominating "cautious" equilibria exist, where subjects collectively demand the low amount of resource – thereby securing positive payoffs – subjects are unable to coordinate on them and either select the (dominated) dangerous symmetric equilibrium or fail to coordinate on any equilibrium at all. Surprisingly, this last outcome is more and more likely as the probability of the "high" state diminishes.

The division of private goods has 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 pool problems in a dynamic setting: Fischer at al. (2004), for example, showed that an increase in uncertainty leads to overly optimistic expectations.

[2] In a context relatively close to ours, Guth et al. (2004) study a Nash demand game 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.

In these papers, and in the following literature (see for example Gustafson et al., 1999, Milinsky et al., 2008 or Tavoni et al. 2011 or Barrett 2012) it is unclear why resource uncertainty affects cooperation. Rapoport et al. (1992) suggested that the overharvesting effect might reflect that subjects overestimate the size of the uncertain resource. 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).

Contrasting with the existing literature, we provide an explanation as to why uncertainty may lead to the subjects' collective optimism: in our setting, dangerous equilibria may exist 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 even when the probability of a "high" state is small. 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.

While our results do not directly explain the findings of the Rapoport papers, which assume a uniform distribution, it is consistent with their explanation emphasizing the role of players basing their estimates of resource size on an aggregated assessment of the lower and upper bounds of the available resource. Pushing this reasoning further we obtain the discrete bimodal distribution we analyze here, with positive weight on the lower and upper bounds of the uniform distribution they consider. The apparent overweighting of the dangerous outcome is not driven by optimism of agents *per se*, but by a coordination problem. Our results confirm this assertion by showing that agents tend to have high belief about the play of other agents, which pushes them toward a dangerous play.

Our formal experimental results are threefold. First, we find that subjects mostly coordinate on the symmetric dangerous equilibrium and rarely coordinate on any cautious equilibria (Result 1) even though almost all agents risk averse. In fact, because we elicit the subjects' beliefs of what their counterparts will play (and reward their accuracy), we are able to test whether they play best-response strategies consistent with a cautious or dangerous outcome: it turns out that, even at the individual level, subjects aim to play the symmetric dangerous equilibrium. Second, the probability of being in the 'high' state plays an important role in achieving coordination: coordination proves more difficult for lower values of this probability (Result 2). This set of results confirm the main theoretical message: a risk-taking society may emerge from the decentralized actions of risk-averse individuals. A surprising result is that despite the "good" properties of the symmetric cautious equilibria (i.e. it is strong and Pareto dominates the symmetric dangerous equilibrium), even risk-averse agents fail to coordinate on it. A likely explanation for this behavior lies in the pessimistic beliefs held by subjects during the experiment: a great majority of players believe that the other agents will collectively ask for more than the safe outcome (Result 3). Thus, a player has no incentive to play cautiously, her best response is simply to play a dangerous outcome: instead of "collective optimism", we observe inefficient behaviors because of "individual pessimism".

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

2 The basic model

Consider a finite set $N = \{1, ..., n\}$ of agents who must simultaneously decide how much of a resource, measured in positive real numbers, 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.[3] Let $0 < \omega_L < \omega_H$ be respectively the low and high value that the stock of resource can take. With probability $p \in [0, 1]$, the high value ω_H is realized, with probability $(1 - p)$, the low value ω_L is realized.

Denote $x_i \in [0, \omega_H]$ agent i's claim, demand or request (we use these terms interchangeably throughout the paper) on the resource, $x = (x_i)_{i \epsilon N}$ 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. 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 (i.e., agents are risk averse or risk neutral) and nondecreasing.

[3]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.

Reaching this consumption level 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* is now given by

$$v_i(x_i, X_{-i}) = u_i(x_i)\mathbb{I}(X \leq \omega_L) + pu_i(x_i)\mathbb{I}(\omega_L < X \leq \omega_H), \tag{1}$$

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

A profile of claims $x \in [0, \omega_H]^n$ is a (pure strategy) Nash equilibrium if for each $i \in N$,

$$v_i(x_i, X_{-i}) \geq v_i(x_i', X_{-i}) \text{ for all } x_i' \in [0, \omega_H] \tag{2}$$

This completes the description of the model, so we can proceed to the derivation of our main results.

3 Main results

We first present the Nash equilibria of this simple game.

3.1 Nash equilibria

Using the current notation, one can characterize an agent i's best response strategy as follows.

First, consider the case where $X_{-i} > \omega_L$:

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

b) If $X_{-i} > \omega_H$, 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 $X_{-i} \leq \omega_L$:

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

b) If $u_i(\omega_L - X_{-i}) < pu_i(\omega_H - X_{-i})$, agent i's best response is $x_i = \omega_H - X_{-i}$.

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

Cautious Equilibrium: An equilibrium profile $x \in [0, \omega_H]^n$ is a *cautious equilibrium* if $X \leq \omega_L$.

Notice that for any cautious equilibrium, expected payoffs are then always positive regardless of p because ω_L is available with certainty – i.e., $v_i(x_i, X_{-i}) = u_i(x_i)$ for all $i \in N$.

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

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 $x \in [0, \omega_H]^n$ is a *dreadful equilibrium* if $X_{-i} > \omega_H$ for all $i \in N$.

Notice that no Nash equilibrium exists in which agents collectively ask for less than ω_L or strictly between ω_L and ω_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). The simultaneous presence of these equilibria is also unlikely to be accidental, as the following simple example suggests.

Example 1. *Let there be only two agents, with identical utility function* $u_i(x_i) = \sqrt{x_i}$ *for* $i = 1, 2$. *Suppose* $\omega_L = 0.8$, $\omega_H = 1$, *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* $x'' = (1.5, 1.5)$ *is also clearly an equilibrium, a dreadful one which brings each agent's payoff to* 0.[4] ◇

[4] Although we exclude such risk attitudes for reasons of tractability, note that all three types of equilibria may coexist with only risk-loving agents. To see this, suppose that $i = 1, 2$, $u_i(x_i) = x_i^2$, $p = 0.4$ and $a = 0.8$. One can check that $x = (0.5, 0.5)$ is a dangerous equilibrium, $x' = (0.4, 0.4)$ is again a cautious one, and $x'' = (1.5, 1.5)$ is a dreadful equilibrium.

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

$$\begin{array}{ll} u_i(\omega_L - X_{-i}) > pu_i(\omega_H - X_{-i}) & \text{if } X_{-i} < \overline{X}_i \\ u_i(\omega_L - X_{-i}) < pu_i(\omega_H - X_{-i}) & \text{if } X_{-i} > \overline{X}_i \end{array}. \tag{3}$$

This allows one to make the following preliminary statement.

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

Proof. Let $f_i(X_{-i}) \equiv u_i(\omega_L - X_{-i}) - pu_i(\omega_H - X_{-i})$. Clearly, $f_i' = -u_i'(\omega_L - X_{-i}) + pu_i'(\omega_H - X_{-i}) < 0$ since the function u_i is concave. When $f_i(0)$ is negative or 0, one can set $\bar{X}_i = 0$. If $f_i(0)$ is positive, the fact that $f_i(a) < 0$ and $f_i(.)$ 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 $X_{-i} > \bar{X}_i$. □

The following proposition indicates when there always exists at least one cautious or one dangerous equilibrium, and when both types of equilibria coexist.

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

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

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

iii) At least one cautious and one dangerous equilibria coexist if and only if $(n-1)\omega_L \leq \sum_{i \in N} \bar{X}_i \leq (n-1)\,\omega_H$.

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

$$\begin{cases} X_{-i} \leq \bar{X}_i & \text{for all } i \in N \\ \sum_j x_j = \omega_L \end{cases} \tag{4}$$

Using the fact that $X_{-i} = \omega_L - x_i$ and adding up all the inequalities in (4), we have that $\sum_i \bar{X}_i \geq (n-1)\omega_L$. Conversely, if $\sum_i \bar{X}_i \geq (n-1)\omega_L$, one can always find a vector x that satisfies (4).

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

$$\begin{cases} X_{-i} \geq \bar{X}_i & \text{for all } i \in N \\ \sum_j x_j = \omega_H \end{cases} \tag{5}$$

Using the fact that $X_{-i} = \omega_H - x_i$ and adding up all the inequalities in (5), we have that $\sum_i \bar{X}_i \leq (n-1)\omega_H$. Conversely, if $\sum_i \bar{X}_i \leq (n-1)\omega_H$, one can always find a vector x which satisfies (5).

Part (iii) follows trivially. □

An important corollary is that dangerous equilibria always exist when $n > \frac{\omega_H}{\omega_H - \omega_L}$, and this independently of the utility profile and probability p: by definition, $\bar{X}_i \leq \omega_L$, which implies $\sum_{i \in N} \bar{X}_i \leq n\omega_L$. Furthermore, we know from (iii) that a dangerous equilibrium exists if $\sum_{i \in N} \bar{X}_i \leq (n-1)\,\omega_H$. Hence, a dangerous equilibrium exists if $n\omega_L \leq (n-1)\,\omega_H$.

Example 2. *Let* $n = 3$*,* $\omega_L = 9$ *and* $\omega_H = 12$*. Notice that the condition* $n > \frac{\omega_H}{\omega_H - \omega_L}$ *is not satisfied. If* $p < \frac{1}{4}$*, then there exist no profile of utility function* u *with, for each* $i \in N$*,* $u_i(x_i) = (x_i)^\alpha$*,* $0 < \alpha \leq 1$*, for which a dangerous equilibrium exists. For each* $i \in N$*, agent* 1*'s expected utility from a symmetric demand* $x = (4, 4, 4)$ *is* $4^\alpha p < 1$ *while one from deviating to the cautious demand* $(1, 4, 4)$ *is simply 1. It can be checked that no asymmetric dangerous equilibrium exists. On the other hand, there exists an infinity of cautious equilibria. For instance. with* $p < \frac{1}{4}$*, the symmetric demand* $(3, 3, 3)$ *is a cautious equilibrium, and so is the asymmetric demand* $(1, 1, 7)$*.* ◇

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 a, the probability p, and the agents' respective utility functions $u_i(\cdot)$.

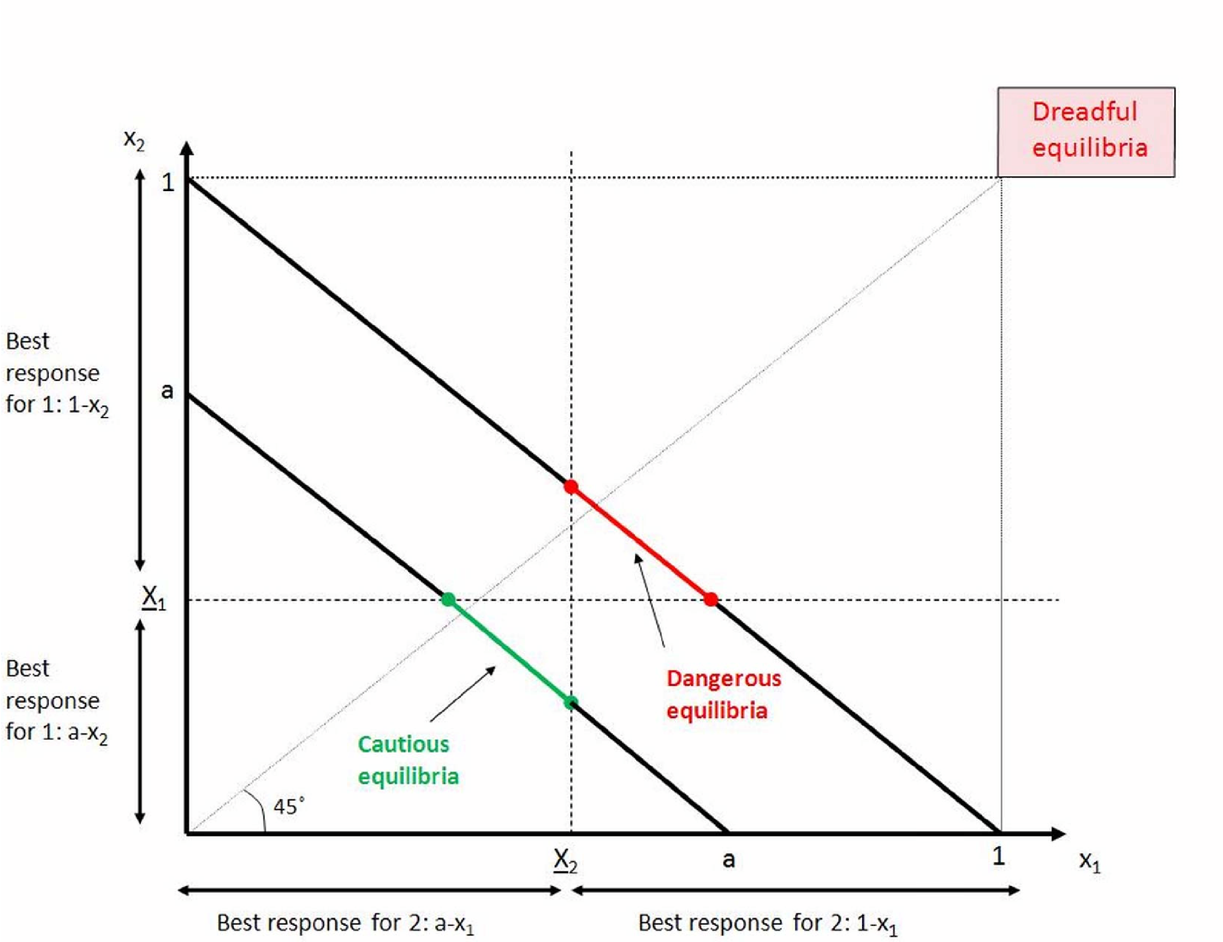


Figure 1: The two agents case

We now discuss a few comparative statics arguments based on Proposition 1. If agent i becomes more risk averse (so the coefficient of absolute risk aversion $u_i''(\cdot)/u_i'(\cdot)$ uniformly increases, say), the cut-off $\bar{X}_i$ increases because a secure amount of resources $(\omega_L - X_{-i})$ now yields relatively more utility than the risky amount $(\omega_H - X_{-i})$. From Proposition 1, one infers that the set of cautious equilibria expands while the set of dangerous equilibria shrinks as agents become more averse to risk. Also, $\bar{X}_i$ is a decreasing function of p.

Finally, consider a change in the level of the lower threshold from ω_L to $\omega_L' > \omega_L$ and denote by $\bar{X}_i'$ the cut-off value associated with ω_L', all else equal. It follows from the concavity of u_i that $\bar{X}_i' > \bar{X}_i$. This implies that the set of dangerous equilibria shrinks. However, the set of cautious equilibria might not expand: by Proposition 1, this will happen if and only if $\sum_N \bar{X}_i' - \sum_N \bar{X}_i > (n-1)(\omega_L' - \omega_L)$.

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. Recall that a Nash equilibrium x is *strong* if no alternative strategy profile $x' \in \mathbb{R}^n_+$ exists such that $x'_j = x_j$ for all the outsiders $j \in N \backslash T$ and $v_i(x') \geq v_i(x)$ for all agents i belonging to a coalition $T \subseteq N$, the inequality being strict for at least one i. 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.*

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 $x'_j = \omega_L - X'_{-j}$ or less leads to a lower payoff than before; her best response must be $x'_j = \omega_H - X'_{-j}$. We then have that $v_j(x'_j, X'_{-j}) = v_j(\omega_H - X'_{-j}, X'_{-j}) < v_j(\omega_H - X_{-j}, X_{-j}) \leq v_j(x)$, 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 $T \subseteq N$,*

$$\begin{aligned} x'_i &= x_i - \alpha_i \qquad \text{for all } i \in T, \text{ and} \\ x'_i &= x_i \qquad \text{for all } i \notin T \end{aligned} \tag{6}$$

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

Proof. Suppose a dangerous equilibrium x and a cautious equilibrium x' verifying condition (6). For all $i \in T$, we have that

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

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). □

Our set of theoretical results can be summarized as follow:

- Cautious and Dangerous equilibria can coexist even though all agents are risk averse (Proposition 1).
- A Cautious equilibrium is Pareto efficient and Pareto-dominates all dangerous equilibria that can be reached from it while increasing every agent's claim (Propositions 2 and 3). An important implication is that the symmetric Cautious equilibrium Pareto dominates the symmetric dangerous equilibrium (if they co-exist of course).

The latter result qualifies the former: even though both types of equilibria may coexist, cautious equilibria may be more likely to emerge due to their appealing robustness and welfare properties. However, as we shall see, our experimental results tend to show that the second part of the statement does not hold in the lab: cautious equilibria very rarely emerge, possibly due to a severe coordination problem.

4 Experimental Design

The experiment took place in the fall of 2011 at BeClaw, the experimental lab at the University of Bern. For this purpose, 138 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 four treatments, three sessions for each treatment, each session involving different participants. Participants earned an average of 40 Swiss Francs for their participations (roughly $44 US).

Each session consisted of two parts. The first part was a 10-period version of a Stochastic Nash Demand Game with fixed p. The second part was a risk-preference elicitation questionnaire where participants filled the Holt and Laury lottery choice tables (Holt and Laury, 2002). Treatments 1-4 had values of $p = 1, 0.7, 0.5$ and 0.3, respectively. Instructions can be found in the appendix.

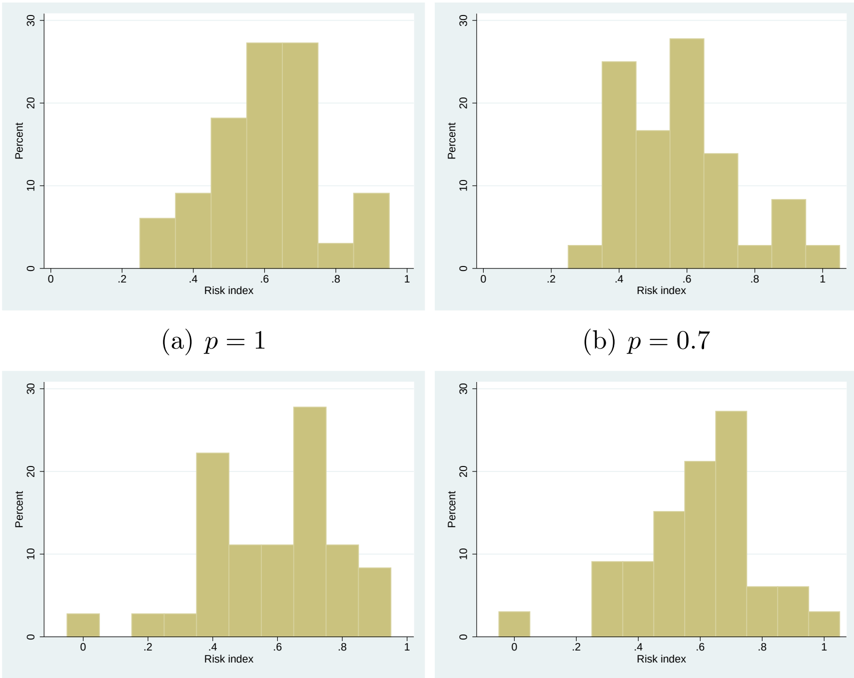
At the beginning of each period, participants are assigned randomly into groups of three. Groups are reshuffled each period and identities are unknown throughout to avoid reputation effects. In each period, groups play the Stochastic Nash Demand Game given the probability p that prevails in the session. The probability p is common knowledge among participants.

We used $\omega_L = 6$ and $\omega_H = 12$ for all treatments, also common knoweldge. For this set of parameters, dangerous equilibria always exist. Cautious equilibria exist depending on the utility profile and p. For $p \leq 0.5$, cautious equilibria exists for a wide set of risk-averse utility profiles –e.g., $u_i(x_i) = (x_i)^\alpha$ for $\alpha \in (0, 1)$, or constant relative risk aversion utility functions (CARA) with relative risk aversion coefficients consistent with the ones obtained from the risk-preferences elicitation portion of the experiment. Notice that for a utility profile $u_i(x_i) = (x_i)^\alpha$ for $\alpha \in (0, \frac{1}{4}]$, cautious equilibria exist for $p \leq 0.7$. Hence existence of cautious equilibria can be rationalized by many utility profiles in the $p = 0.7$ treatment as well.

Treatment	1	2	3	4
Probability	1	0.7	0.5	0.3
Number of Subjects	33	36	36	33

Table 1: Experimental Design

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.) summarizing the Stochastic Nash Demand Game in which they will take part. Control questions assess the understanding by participants. The experiment does not start until each participant has answered correctly the control questions. The first part lasts for ten periods. Each period is decomposed into two parts. 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 one extra experimental dollar. If his estimation deviates by one, he receives 0.75 extra experimental dollar. If his estimation differs by 2 points,



(a) $p = 1$ (b) $p = 0.7$

(c) $p = 0.5$ (d) $p = 0.3$

Figure 2: Risk preferences

he gets 0.5 extra experimental dollar. If it differs by more, he gets nothing. 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. Participants are informed that there will be a second part to the experiment, they have however no knowledge of what this part will be about or whether they would get money from it. The second part of the experiment is a standard risk preferences elicitation as done by Holt and Laury (2002). We refer the reader to that paper for additional details.

5 Experimental Results

Over all treatments, almost half of the outcomes are Nash equilibria (47%). The rate of Nash equilibria is 68% when $p = 1$, 64% when $p = 0.7$, and drops to 35% when $p = 0.5$ and 23% when $p = 0.3$. We first show that, even though agents are mostly risk averse, almost all of these equilibria are Dangerous (Result 1). We then stress that coordination failure increases for lower values of p (Result 2). Finally we establish that these dangerous behaviors are mainly driven by pessimistic beliefs of players (Result 3). This confirms that risk aversion, by itself, does not always push toward an efficient outcome in a risky environment. We start with an overview of the statistical observations pointing at our main results before exposing them formally.

5.1 Overview and first impressions

We give here an overview of important parameters and quantities coming out of our experiment. This will help us forming some first intuitions regarding the three central results of the experiment. We first start with an account of risk preferences before detailing beliefs and demands of players.

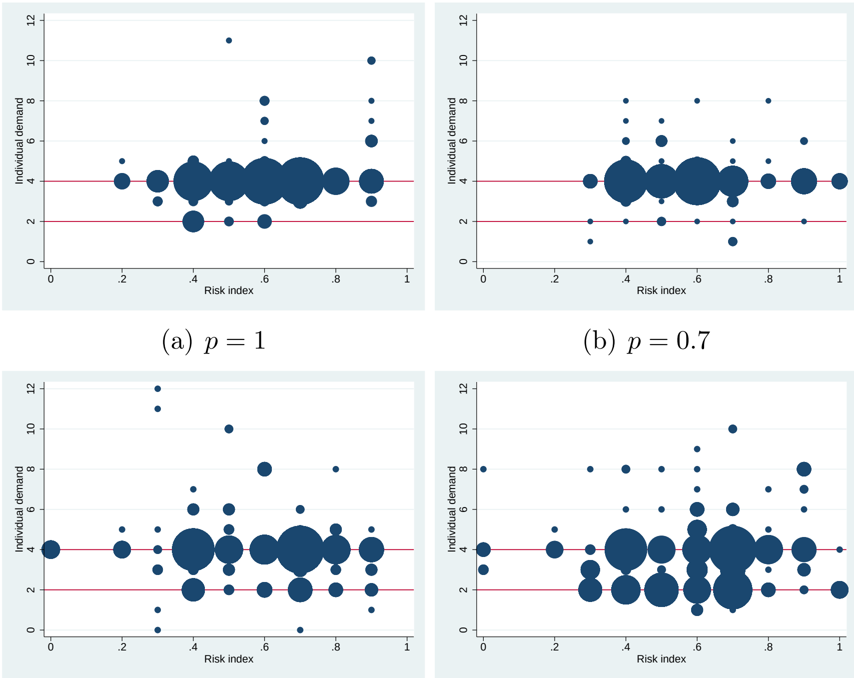
Risk Preferences. Risk indices are constructed following the elicitation of the attitude toward risk of subjects. In the second part of the experiment, subjects have a list of 10 decisions to make, each decision involving the choice between two lotteries –A and B– which differ in their expected value. The number of successive choices is indicative of the attitude towards risks of subjects with the risk neutral switching between lotteries A and B after the fourth decision. We simply record the decision at which a subject switches between lottery A and B.[5] Let this decision be y for subject i. Define agent i's *risk index* by $\rho_i \equiv y_i/10 \in [0,1]$. Subject i is risk neutral if $\rho_i = 0.4$, risk-lover if $\rho_i < 0.4$ and risk-averse if $\rho_i > 0.4$.

Figure 2 shows the distribution of the risk index in each treatment. The average risk index is roughly at 0.6 in all treatments, indicating moderate risk-aversion on the part of the subjects.[6] We find no statistical difference in the distribution of the risk indices across treatments –Kruskall-Wallis test, p-value= 0.84. For all treatments, a Wilcoxon-matched-pairs-signed rank test cannot reject the null hypothesis that the median risk index is 0.6 –p-values 0.8786, 0.4579, 0.7764, and 0.9072 for Treatments 1, 2, 3 and 4 respectively.

In contrast with previous literature—and in line with our theoretical results—we observe in Figure 3 an apparent lack of relationship between individual demands and risk preferences. This is supported by non-significant Spearman correlation tests (although one can notice some mild differences across treatments as the probability p goes down). We will confirm in the next section that risk aversion does not mitigate the coordination problem leading to more dangerous outcome.

[5] Only a few subjects (no more than 3 per session per treatment) displayed multiple switching patterns. For those subjects, we keep only the first switch as is standard in the litterature.

[6] The average risk indexes are, respectively, 0.606 in treatment 1, 0.580 in treatment 2, 0.583 in Treatment 3, and 0.590 in treatment 4.



(a) $p = 1$

(b) $p = 0.7$

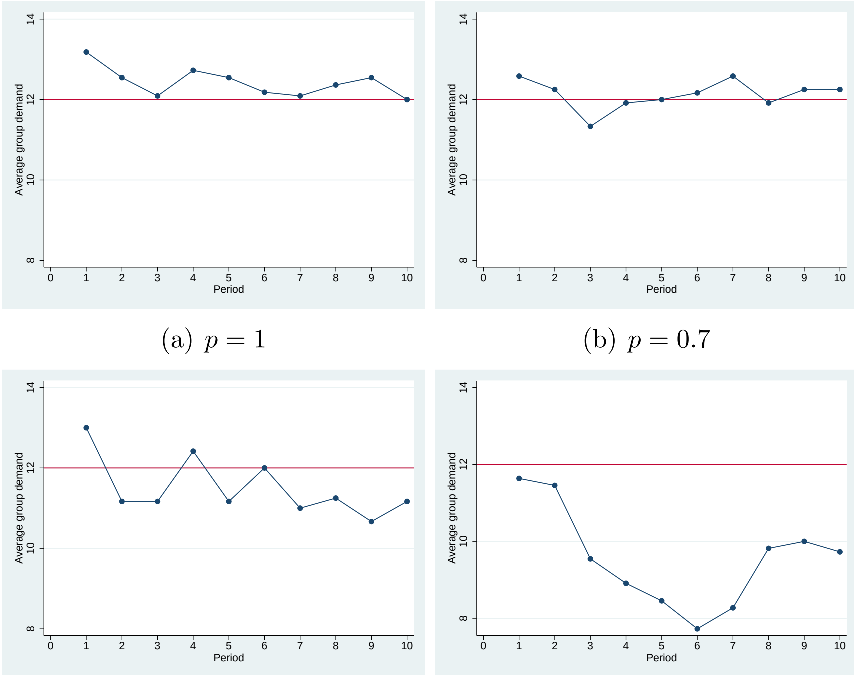
(c) $p = 0.5$

(d) $p = 0.3$

Figure 3: Relationship between Risk Preferences and Individual Demands

Beliefs. The main observation is that a vast majority of subjects in our sample have pessimistic beliefs. The average belief across all treatment is higher than 6 in 87% of the observations. These beliefs are higher than 6 in 96% of the observations when $p = 1$, 92% of the observations when $p = 0.7$, 91% of the observations when $p = 0.5$ and 63% of the observations when $p = 0.3$. It is noteworthy that, even in the latter treatment, the beliefs are strongly biased toward high claim values. Even more surprising, is that the beliefs of players are higher than 8 in 91% of the observations when $p = 1$, 92% of the observations when $p = 0.7$, 71% of the observations when $p = 0.5$ and 41% of the observations when $p = 0.3$.

Recall that if a player believes that the other agents will collectively ask for more than 6, then she has no incentive to play a small amount because a cautious outcome is unreachable. Her best response is simply to play so as to collectively reach $\omega_H = 12$, a dangerous outcome. Such beliefs induce best responses away from a cautious (and efficient) equilibrium. These pessimistic beliefs may explain the next stylized fact: subjects have a clear tendency to avoid cautious play.



(a) $p = 1$ (b) $p = 0.7$

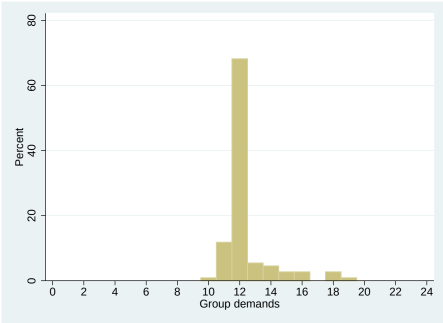
(c) $p = 0.5$ (d) $p = 0.3$

Figure 4: Trend of average groups demand

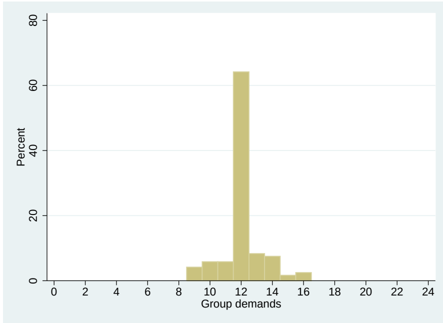
Demands. We observe that subjects mostly coordinate on the symmetric dangerous play when playing an equilibrium. If this trend appears when studying group demands, it becomes even clearer when considering the individual demands.

Figure 5 shows the distribution of group demands, independently of the period in which they occur. We observe that, on average, agents play collectively close to the symmetric dangerous equilibrium—i.e., total demands around $\omega_H = 12$—in each treatment but the one with $p = 0.3$. In the $p = 1$ treatment, the average group demand across periods is 12.42 with a standard-deviation of 0.36. When $p = 0.7$, the average group demand across periods is 12.12 with a standard-deviation of 0.36. When $p = 0.5$, the average group demand across periods is 11.5 with a standard-deviation of 0.72. Finally, when $p = 0.3$, the average group demand across periods is 9.55 with a standard-deviation of 1.28.

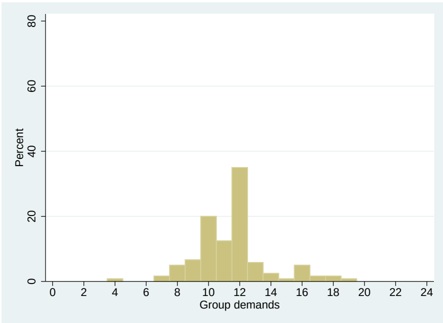
In all treatments, Wilcoxon matched-pair tests run in Period 1 never reject the null hypothesis that agents median play is 4, with p-values respectively of 0.5517, 0.3742, 0.6339, and 0.2276. Although independence of observations bound us to use this test in Period 1 only, we nevertheless (cautiously) report next the outcomes of such test run in later periods. As it turns out, with $p = 1$ or $p = 0.7$, the null is never rejected in later periods. With $p = 0.5$, the null is rejected in periods 7 to 10. With $p = 0.3$, the null



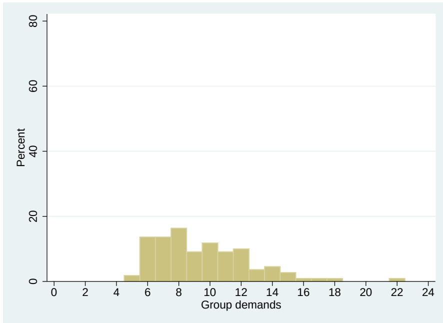
(a) $p = 1$



(b) $p = 0.7$



(c) $p = 0.5$



(d) $p = 0.3$

Figure 5: Sum of demands by group

is rejected from Period 3 to 10. However the null hypothesis that agents' demand is 2 (coordination on being cautious) is always rejected.

The last observation is that, as p goes down, agents play less and less dangerous but do not coordinate easily on any cautious equilibrium. Table 2 shows the proportion of Nash equilibrium occurrences across period and treatments, irrespective of whether they are cautious or dangerous equilibria (disaggregated data can be found in Tables 6 and 7, in the Appendix). We see that as p goes down a coordination problem emerges: agents coordinate less and less on any equilibrium. Despite the fact that the dangerous play becomes less and less attractive as p shrinks, agents are reluctant to play cautiously. Indeed, in the $p = 1$ treatment, 75 out of 110 observations are dangerous equilibria. When $p = 0.7$, 77 out of 120 observations are dangerous equilibria. When $p = 0.5$, 42 out of 120 observations are dangerous equilibria. *Perhaps strikingly, in the former three treatments, no cautious equilibrium was ever played.* Finally, when $p = 0.3$, 10 out of 110 observations are dangerous equilibria and only 16 are cautious equilibria. In contrast, overshooting is roughly at the same level in the first three treatments –respectively 21, 24 and 22 observations. When $p = 0.3$, 16 observations are above a group demand of 12 –out of which ten occur in the first two periods of play. We now confirm statistically these first impressions by stating

Nash Equilibrium Rates				
Period	0.3	0.5	0.7	1
1	0.272727	0.083333	0.583333	0.636364
2	0.181818	0.166667	0.5	0.272727
3	0.181818	0.083333	0.666667	0.818182
4	0.272727	0.25	0.75	0.454545
5	0.181818	0.333333	0.5	0.545455
6	0.363636	0.666667	0.583333	0.727273
7	0.181818	0.5	0.666667	0.727273
8	0.363636	0.416667	0.75	0.727273
9	0.181818	0.5	0.666667	0.909091
10	0.181818	0.5	0.75	1
Average	0.236364	0.35	0.641667	0.681818

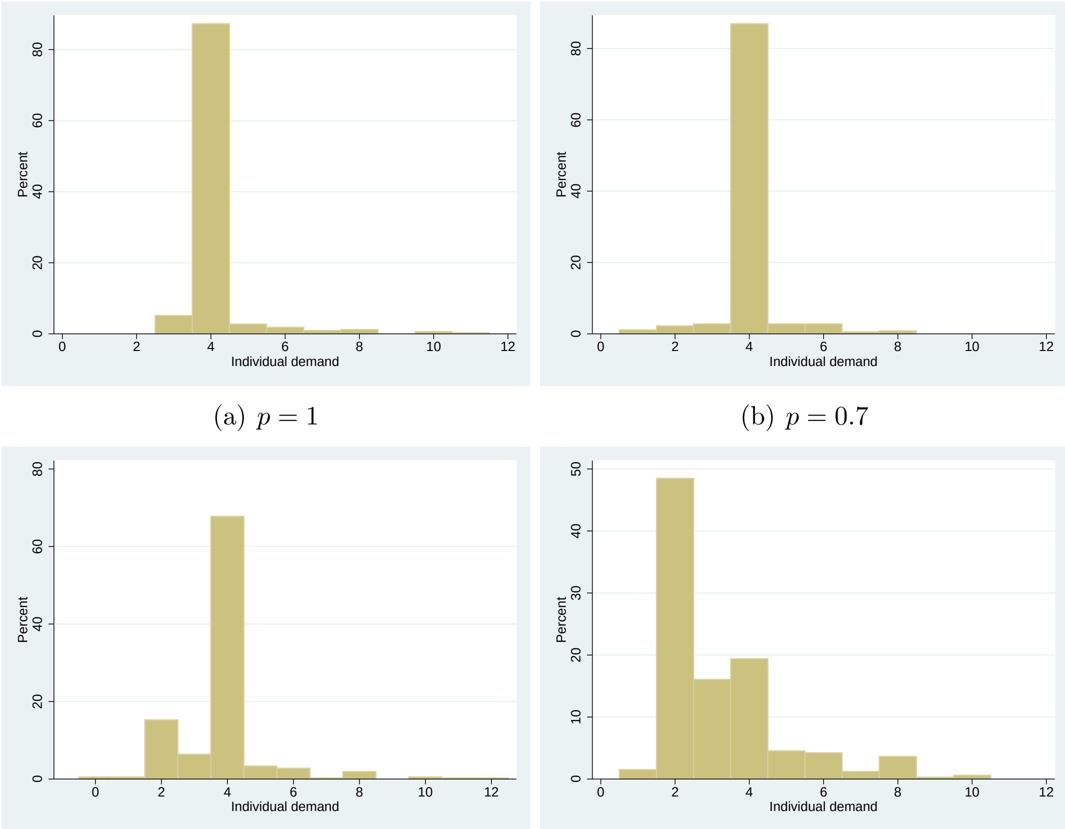
Table 2: Nash Equilibrium Rates

formally our three main experimental results.

5.2 Formal results

Result 1: Equilibria are mostly Dangerous. In all treatments, Wilcoxon matched-pair tests run in Period 1 never reject the null hypothesis that groups play 12 collectively –p-values respectively of 0.4615, 0.2032, 0.4081, and 0.47. As said before, we can only run this test with confidence in period 1 because observations are no longer independent in Period 2 onward. With this caveat in mind, we nevertheless report next the outcome of such tests beyond the first period before completing the analysis with two regressions explaining both type of play (cautious and dangerous).

With $p = 1$, the null is never rejected. We take this as sufficient evidence that there is no coordination problem in the deterministic Nash Demand Game. It follows that any coordination failure we will encounter will be entirely attributable to the presence of uncertainty in the amount of resource available. With $p = 0.7$, the null is never rejected either. This confirms that coordination is possible even for $p < 1$. With $p = 0.5$, the null is rejected in periods 9 and 10. With $p = 0.3$, the null is rejected in period 3 onwards. However the null hypothesis that groups collectively demand 6 is always rejected, which implies that the cautious equilibrium is rarely reached. It appears that a coordination problem emerges as we lower the probability that the high value is realized. As a counterpart, we test whether the sum of demands statistically differs from a sum of demands of 6. For all the



(a) $p = 1$

(b) $p = 0.7$

(c) $p = 0.5$

(d) $p = 0.3$

Figure 6: Distribution of individual demands by treatment

treatments with uncertainty, the null hypothesis that agents coordinate on playing the cautious equilibrium is rejected in all periods, and at the 1% level.

We complement these findings with a Kruskall-Wallis test on Period-1 group demands to check whether there are differences in the distributions of group demands across the four treatments –p-value=0.6057. When extending the test to later periods, we find the null hypothesis to be rejected in Period 4 onwards. Hence there seems to be significant shift in the similarity of group behaviour across treatments after some experience is gained. Table 2 and Figure 4 already indicated some disparities across treatments. Figure 4 showed the salience of 12 as group demand in all but the $p = 0.3$ treatment. The rate of dangerous equilibrium from $p = 1$ to $p = 0.5$ are, respectively, 68%, 64% and then 35%. In the $p = 0.3$ treatment, this rate drops to 9% (10 observations out of 110) while the rate of a cautious equilibrium being played is still only 14.5% (16 observations out of 110).[7]

[7]Recall that coordination on the symmetric cautious equilibrium is rejected according to the Wilcoxon matched-pair tests.

Probit regression			
Dangerous individual demand			
	Coefficient	Std-error	P-value
Period	0.036153	0.017275	0.036
Belief ≥ 6	1.385512	0.206568	0.000
Lagpayoff	0.071060	0.029884	0.017
Risk averse	0.060938	0.192834	0.752
DummyT3	-0.553402	0.227114	0.015
DummyT4	-1.664540	0.226226	0.000
Constant	-0.543815	0.283394	0.055
Observations	945		
Log likelihood	-427.11535		

Table 3: Determinants of a symmetric dangerous demand

The tendency to adopt dangerous behavior is even clearer when we study individual demands. We run a probit regression to evaluate the determinants of the probability of playing the dangerous (symmetric) demand strategy: the dependent variable takes value 1 if the demand by subject i in period t is 4, and 0 otherwise. As independent variables, we include *period* to capture whether there is a time trend –e.g. learning. The variable *belief* $\geq$ 6 takes value 1 if the belief of subject i in period t is higher than 6, and 0 otherwise. Recall that a belief higher than 6 render the cautious play irrelevant. We add a lag variable, *lagpayoff*, which is subject i's payoff of in Period $t-1$. Under the hypothesis that risk preferences may influence behavior, we also include a dummy for risk aversion –value equal to 1 if $\rho_i \geq 0.6$, the average risk-aversion rate in our data, and 0 otherwise– as potential explanatory variable. Finally, we add dummy variables to capture whether there is a treatment effect. The reference point is Treatment 2 with $p = 0.7$.[8] We run a probit regression with robust standard errors clustered at the subject level. Results are reported in Table 3.

We see that time has a significant impact on demanding 4, as well as the payoff obtained in the previous period. Interestingly, the fact that agents are risk-averse has no significant impact on the probability of playing dangerously (in line with our theoretical results). However, in the $p = 0.5$ and $p = 0.3$ treatments, there is a significant shift in the probability of playing dangerously –p-values of 0.015 and below 0.001. Hence, even though agents' individual behavior across treatments is statistically hard to distinguish—with the exception of the $p = 0.3$ treatment—the probability of focusing on the dangerous

[8]Treatment 1, where $p = 1$, is not considered here.

Probit regression			
Cautious individual demand			
	Coefficient	Std-error	P-value
Period	-0.006441	0.021220	0.761
Belief ≥ 6	-1.137815	0.2620155	0.000
Lagpayoff	-0.016733	0.034265	0.625
Risk averse	-0.1497	0.238320	0.530
DummyT3	0.909623	0.227349	0.001
DummyT4	1.654761	0.257209	0.000
Constant	-0.798751	0.323718	0.014
Observations	945		
Log likelihood	-339.34841		

Table 4: Determinants of a symmetric cautious demand

equilibrium strategy is clearly influenced by uncertainty. Finally, we see that having a high belief plays a statistically significant (and quantitatively important) role in the likelihood of adopting a dangerous play. We will address this important point in the next subsection.

In order to conclude this analysis we present a probit regression to evaluate the determinants of the probability of playing the cautious (symmetric) demand strategy, including the same independent variables (Table 4). Surprisingly, we see that apart from the probability p, only the variable capturing the high belief of agents have an explanatory power (quantitatively important and negative). Once again risk aversion does not explain the behavior of agents, an observation consistent with our theoretical results. Complementing this with our earlier non-parametric statistical tests, we see that having agents focusing less on the dangerous equilibrium does not imply coordination on the cautious strategy. This regression confirms that the pessimistic beliefs of agents play a central role in explaining the coordination failure on the Cautious equilibrium, we will develop further this argument at the end of this section.

Result 2: Coordination failure increases a p goes down. The main observation here is that equilibrium behavior seems to differ across treatments. We saw in the "overview" subsection that there is an apparent relationship between probabilities and noise in group coordination. To check for this, we run a Spearman correlation test between p and the standard deviation in average group demands in the corresponding sessions. We find a correlation coefficient that is indeed negative $-\rho = -0.7341-$ and the relationship between p and noise in coordination is significant at the 1% level –p-value=0.0066.

While our Wilcoxon test confirmed the statistical significance of group demands being concentrated around 12, we see that the equilibrium rate when $p = 0.5$ is 8% in period 1 (1 observation out of 12). On the other hand, it is 63% and 58% when $p = 1$ and $p = 0.7$, respectively. In the $p = 0.3\%$, this rate is 27% –and no cautious equilibrium was played in period 1. Figure 4 and Table 2 already indicated that decrease in probabilities seem to erode the focus on playing the symmetric dangerous equilibrium.

Likewise, in the first two treatments, only 14 and 19 observations are below 12, respectively. In the last two treatments, 56 and 83 observations are below 12. Hence decrease in probabilities are linked to increase in systematic shifts from playing a dangerous equilibrium –although we have seen in the previous probit regression that it is only when $p = 0.3$ that such shifts are statistically significant. However, recall that in that treatment, there is no coordination on playing a cautious equilibrium –out of 110 observations, only 16 are cautious equilibria. Hence, statistically significant shifts from a dangerous equilibrium lead to a significant non-equilibrium behavior. In addition, a Spearman correlation test confirms the positive relationship between Nash equilibrium play and p: $\rho = 0.7584$ with a p-value below 1%. Hence a decrease in p not only decreases the probability to observe dangerous equilibrium being played, but it also decreases the likelihood of witnessing (pure strategies) equilibrium play.

Result 3: Deviation from the Cautious play is due to pessimistic beliefs We have seen from the results of the probit regressions in tables 3 and 4 that having a high belief i) decreases the likelihood of playing the symmetric cautious strategy and ii) increases the likelihood of playing the symmetric dangerous strategy. We saw in the overview that agents have overwhelmingly pessimistic beliefs: this belief is higher than 6 in 96% of the observations when $p = 1$, 92% of the observations when $p = 0.7$, 91% of the observations when $p = 0.5$ and 63% of the observations when $p = 0.3$. The main observation is that all these are significantly higher than 6 (at the 1% level using Wilcoxon signed-rank test). The prevalence of pessimistic belief is thus the main empirical regularity (in our sample) consistent with the coordination failure we observe in the data.

In order to have a more formal view on the impact of beliefs on the cautious play, we present in Table 5 a probit regression (clustered on subjects) to evaluate the determinants of the probability of playing the cautious (symmetric) demand strategy, just for the last treatment ($p = 0.3$, the only treatment in which we observe cautious equilibria). An important result appears when computing the marginal effect of the variable "belief ≥ 6" on the variable "symmetric cautious demand": this value is -0.36 (p-value 0.002), meaning that having a high belief decreases the probability of playing the symmetric cautious play

Probit regression			
Cautious individual demand: Treatment 4, $p = 0.3$.			
	Coefficient	Std-error	P-value
Period	0.008046	0.028668	0.779
Belief ≥ 6	-0.966602	0.350842	0.006
Lagpayoff	0.038318	0.056156	0.495
Risk averse	-0.409930	0.347742	0.238
Constant	0.772578	0.444961	0.083
Observations	297		
Log likelihood	-180.63758		

Table 5: Determinants of a symmetric cautious demand in the $p = 0.3$ treatment

(i.e. a claim of "2") by 36% in this treatment.

6 Remarks on overshooting behavior.

Despite its robustness to group deviations and their Pareto-domination of the symmetric dangerous equilibrium, the symmetric cautious equilibrium is rarely reached due to pessimistic beliefs about what others will play. Furthermore, a p goes down, we observe less (pure strategies) equilibrium play. We present a potential explanation, based on mixed-strategy equilibria, which may explain the reluctance of agents in focusing on a cautious play when the probability decreases. Finally, we explore how our findings may shed light on earlier experiments from the psychology literature.

6.1 Non-Robustness of Cautious Equilibria.

One alternative explanation for the few observed numbers of "cautious" equilibria is its sensitivity to deviations of other agents. We provide an example to illustrate this intuition, using the concept of mixed strategies: if an agent thinks that the other agents will play the dangerous strategy with a positive probability (i.e., they are mixing between the "cautious" and the "dangerous" play), playing "Cautious" loses a lot of its appeal. Indeed, even a slight deviation from a cautious strategy (i.e., a small probability for another agent to deviate to a dangerous play) leads the outcome out of the cautious state. Interestingly, whenever dangerous and cautious equilibria coexist, there may exist a symmetric mixed strategy equilibrium in which agents randomize between the cautious and the dangerous strategies.[9]

Consider the example where $n = 3$, $\omega_L = 6$, $\omega_H = 12$, and $u_i(x_i) = \sqrt{x_i}$ for each $i \in N$. Given the experimental evidences we gathered, we thus restrict our attention to the following set of pure strategies $x_i \in \{2, 4\}$. Denote by q_i the probability that agent i plays 4. In a symmetric mixed-strategy equilibrium, $q_i = q_j = q^*$ for all $i, j \in N$. Recall that dangerous and cautious equilibria co-exist for $p \leq 0.5$. The relationship expressing the equality between playing the cautious or the dangerous strategy is given by $p = \frac{(1-q^*)^2\sqrt{2}}{2+(q^{*2}-2q^*)\sqrt{2}}$. Notice that if a symmetric mixed strategy equilibrium is played, its expected utility coincides with the one of the symmetric dangerous equilibrium, i.e. $2p$. In addition, q^* is decreasing in p, i.e. $\frac{dq^*}{dp} < 0$.

When $p = 0.5$, mixing requires that $q^* \approx 0.23$. One striking feature of this example is that an agent will stick to the dangerous strategy even though he thinks that other agents play dangerous with a low probability (i.e. $q_j \geq 0.23$), a value lower than the true probability of observing the high threshold ($p = 0.5$). Using the formula above, one can easily check that this remains true for a wide range of parametrization. This illustrates a "fragility" of the cautious equilibrium: Because even a slight upward deviation brings the system to an uncertain state, the best response of any agent to this upward deviation is thus to play dangerously. This may explain why agents seem reluctant to play the cautious equilibrium and tend to stick to the dangerous one, even when p is low. Even though they observe that the dangerous play is more and more risky, it is difficult for them to coordinate on the cautious equilibrium.

We observe two patterns in the data consistent with this line of explanation: 1) we see that the number of "switches" in demand (between 2 and 4) increases when p decreases, 2) the variance in individual demand increases when p decreases (see Table 8, in the Appendix). These two observations may imply that, even though agents are more and more reluctant to playing the dangerous strategy, they are unable to commit fully to cautious play. We are unable to check formally if agents are playing a mixed strategy, because the (far more complicated) belief elicitation would have blurred the main focus of the paper. However, given the seriousness of the coordination failure, this is definitely an interesting step for further research.

For a given p, an increase in the degree of risk-aversion typically increases the probability that a symmetric mixed strategy equilibrium exists. For instance, let $u_i(x_i) = (x_i)^{\frac{1}{4}}$ for

[9] There may obviously be other more complicated mixed strategy equilibria. We did not check for these. Our interest here is linked to subjects seeing the symmetric cautious and dangerous strategies potentially as focal points. As mentioned above, characterizing the set of mixed strategies equilibria is beyond the scope of this paper.

each $i \in N$. Then for $p = 0.5$, there exists a mixed-strategy equilibrium with $q^* \approx 0.56$. Notice that within the class of utility functions $u_i(x_i) = (x_i)^\alpha$, $\alpha \in (0,1)$, for a given p there is a monotone relationship between α and q^*.

Finally, given a utility profile, within the range of p for which a mixed strategy equilibrium exists, the expected utility obtained at such equilibria is decreasing with p. The same is thus true for the utility obtained at the symmetric dangerous equilibrium –since it coincides with the utility obtained at a symmetic mixed strategy Nash equilibrium.

6.2 On collective optimism.

Our experimental results display a significant amount of overshooting. In previous works, this has been interpreted as if subjects were collectively overly optimistic about the outcome, which would be consistent with research demonstrating that agents tend to weight more heavily desirable outcomes (Zakay, 1983).

While this explanation deserves some credit, we deem it unlikely to explain the phenomenon entirely. In fact, in light of our theoretical and empirical findings based on strategic interaction, we believe this apparent collective optimism to be the symptom of a coordination problem. Indeed, the overshooting we observe is of a very specific kind, whereby agents coordinate precisely on the highest possible amount of available resource. This attests to the existence of an equilibrium whereby agents collectively behave as if the threat of resource scarcity were nonexistent. In the theory portion (Section 2) we identified the existence of such "dangerous" equilibria.

The reason why such equilibria seem to be favored when other, Pareto-dominant equilibria exist seems to be driven by pessimistic beliefs of agents (Result 3): instead of "collective optimism" we observe inefficient behaviors because of "individual pessimism".

The coordination problem explanation seems plausible, not only because it is consistent with our empirical findings, but also because it seems to shed light on similar behavior that other scholars have observed before us. Indeed, the division of private goods has received much interest in the psychology literature, investigating the effects of resource uncertainty on cooperative behavior in experimental settings similar to ours (Budescu, Rapoport and Suleiman, 1992; Budescu, Suleiman and Rapoport, 1995; Rapoport et al., 1992; Suleiman, Budescu and Rapoport, 1994), but with a major difference in the type of uncertainty involved: theirs is modeled by a uniform probability distribution which, unlike ours, is both continuous and unimodal. Their common finding was that as the spread in the distribution increased, subjects tended to overestimate resource size more often. One explanation (Rapoport et al., 1992) is that people are cognitively limited in their grasp of probability distributions and may base their estimates of resource size on a weighted average of the lower and upper bounds rather than consider the full spectrum of possible realizations. In other words, although these subjects were facing a uniform distribution, they behaved as if the resource size was distributed according to a discrete bimodal distribution, precisely like in our setting. If this is indeed the case, the subjects of these experiments were effectively playing a Stochastic Nash Demand Game, possibly coordinating their actions on a dangerous equilibrium.

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7 Appendix

7.1 Tables

Individual demand	0.3	0.5	0.7	1
0	0	2	0	0
1	5	2	4	0
2	**160**	**55**	**8**	**0**
3	53	23	10	17
4	**64**	**244**	**313**	**288**
5	15	12	10	9
6	14	10	10	6
7	4	1	2	3
8	12	7	3	4
9	1	0	0	0
10	2	2	0	2
11	0	1	0	1
12	0	1	0	0
No. Observations	330	360	360	330

Table 6: Distribution of Individual Demands

Cautious or Dangerous Strategy	**0.3**	**0.5**	**0.7**	**1**
2	160	55	8	0
4	64	244	313	288
No. Observations	224	299	321	288
Proportions	0.678788	0.830556	0.869444	0.8

Table 7: Distribution of Symmetric Nash Strategies

Individual Demand								
Period	0.3		0.5		0.7		1	
	Mean	St Dev	Mean	Std Dev	Mean	St Dev	Mean	St Dev
1	3.878788	2.420712	4.333333	2.17781	4.194444	0.855885	4.393939	1.712808
2	3.818182	1.959824	3.722222	1.632021	4.083333	0.840918	4.181818	0.882275
3	3.181818	1.570321	3.722222	1.649435	3.777778	0.590937	4.030303	0.394085
4	2.969697	1.357499	4.138889	1.658791	3.972222	0.73625	4.242424	1.000947
5	2.818182	1.356801	3.722222	1.185896	4	0.755929	4.212121	0.892944
6	2.575758	1.173411	4	0.985611	4.055556	0.82616	4.060606	0.428617
7	2.787879	1.293193	3.666667	0.828079	4.194444	0.821825	4.030303	0.585494
8	3.272727	1.858641	3.75	0.769972	3.972222	0.506309	4.121212	0.73983
9	3.333333	1.652019	3.638889	0.866941	4.055556	0.79082	4.181818	1.044466
10	3.242424	1.369998	3.722222	0.741085	3.972222	0.506309	4	0
Average	3.187879	1.601242	3.841667	1.249564	4.027778	0.723134	4.145454	0.768147

Table 8: Statistics on Individual Demands across Periods

7.2 Instructions (For Online Publication)

We attach below the instructions used in the experiment. Two sets of instructions are shown. The first one refers to Part 1 of Treatment 1 (p=0.7). The second one refers to Part 2 where subjects played the Holt and Laury lotteries task. Recall that subjects knew that there would be two parts in the experiment. However, they had no knowledge of the content of Part 2 while playing Part 1.