2020

04

Working Paper

INSTITUTO DE POLÍTICAS Y BIENES PÚBLICOS (IPP)

Team Formation in Coordination Games with Fixed Neighborhoods

Alejandro Caparrós, Esther Blanco, Philipp Buchenauer and Michael Finus

INSTITUTO DE POLÍTICAS Y BIENES PÚBICOS – CSIC

Instituto de Políticas y Bienes Públicos
Consejo Superior de Investigaciones Científicas
C/ Albasanz, 26-28
28037 Madrid (España)

Tel: +34 91 6022300
Fax: +34 91 3045710

http://www.ipp.csic.es

How to quote or cite this document:

Caparrós, A., Blanco, E., Buchenauer, P., Finus, M. (2020). Team Formation in Coordination Games with Fixed Neighborhoods. Instituto de Políticas y Bienes Públicos (IPP) CSIC, Working Paper. 2020-04

Available at: digital.csic.es

Team Formation in Coordination Games with Fixed Neighborhoods

Alejandro Caparrós*, Esther Blanco†, Philipp Buchenauer‡ and Michael Finus§

Abstract: This study contributes to the recent experimental literature addressing the role of team formation in overcoming coordination failure in weakest-link games. We investigate the endogenous formation of teams in fixed neighborhoods in which it is not possible to exclude players from influencing the weakest-link. Our experimental results show that team formation helps in overcoming the coordination problem, raises equilibrium provision levels, but falls short of providing the Pareto-optimal contribution. As the problem of multiplicity of Nash equilibria in weakest-link games is exacerbated when team formation is introduced, we provide Quantal Response Equilibrium (QRE) and Agent QRE analyses. The analysis demonstrates that team formation would solve the problem with (almost) perfectly rational agents, but also that our experimental results are consistent with (A)QRE models under bounded rationality.

JEL Classifications: C72, C91, C92, H41

Key words: Weakest-link, Coalition Formation, Experimental Economics, Quantal Response Equilibrium, Agent Quantal Response Equilibrium

* Institute for Public Goods and Policies, Spanish National Research Council (CSIC), 28037, Madrid, Spain. Tel: 0034916022536. Email: alejandro.caparros@csic.es (corresponding author).

† Department of Public Finance, University of Innsbruck, Austria; and The Ostrom Workshop, Indiana University, USA.

‡ Department of Public Finance, University of Innsbruck, Austria.

§ Department of Economics, University of Graz, Austria and Department of Economics, University of Bath, UK.

1. INTRODUCTION

Coordination problems in weakest-link games prevail in different types of organizations, including families or teams in firms; and in the adoption of technology, production standards, or efforts to fight a pandemic, among others. In these settings, the smallest effort or contribution determines the payoff of all. There are multiple Nash equilibria, which can be Pareto-ranked, but as many experiments have confirmed, coordinating on the Pareto-optimal equilibrium is far from trivial in practice. There is a long experimental tradition aiming at identifying the determinants of coordination failure and success (Van Huick et al 1990; Cooper et al 1990; Cachon and Camerer 1996; Feri et al 2010). The common pattern observed in coordination experiments with Pareto-ranked equilibria are low contribution levels and a downward sloping trend of average and minimum contribution levels as the game proceeds (see Devetag and Ortmann 2007 for a review), which leads to overall inefficiency. It has been shown that such discouraging results can be alleviated, for example, by introducing financial incentives (Brandts and Cooper 2006; Hamman et al 2007), reducing effort costs (Goeree and Holt 2005; Brandts et al 2007), imposing costs to enter the game (Cachon and Camerer 1996), and advice by players who have played in previous rounds (Chauduhri et al 2009).

In this study, we explore the role of team formation for coordination. The coordination problems we consider is the Van Huick et al (1990) weakest-link game, henceforth abbreviated VHBB, and the "riskier" weakest-link game, first introduced by Feri et al (2010), henceforth abbreviated FIS. In VHBB, agents have incentives to coordinate on high contribution levels, which result in high individual and group welfare, but also face strong strategic uncertainty, as one single player suffices to cause substantial losses to all other group members if her contributions are below those of others. In FIS, failure to coordinate entails even higher losses.[1] The team formation process that we analyze allows, but does not force, agents to endogenously form teams whereby they agree on common effort levels by consensus. We consider situations with fixed neighborhood (group) composition. Therefore, outcomes derive from the effort of the endogenously formed team and also from individual efforts of those group members that do not participate in the team, if any. Hence, when all group members join the team, teams eliminate the strategic risk. However, as long

[1] FIS introduce this payoff table to construct an environment which, intuitively, reinforces the attraction of choosing the worst outcome. Our theoretical analysis in section 5.1 proofs that this intuition is correct.

as one group member does not join the team, teams reduce the strategic risk but do not eliminate it.

This study contributes to a recent and (still) small literature addressing how the type of interaction among group members and the institutional setting affect coordination outcomes in coordination games. Weber (2006) shows that small groups that coordinate efficiently can slowly grow into large and efficiently coordinating groups. A necessary, but not sufficient condition, is that the exogenously defined new entrants are exposed to the groups' history of the minimum contribution levels played in all previous periods. Salmon and Weber (2017) further explore mechanisms allowing small groups to efficiently coordinate in order to grow by incorporating members from low coordination groups. A quota system restricting the number of entrants and a quiz testing the understanding of the game perform roughly equally well to obtain and maintain efficient coordination. In addition, FIS compare decisions by individual and exogenously defined teams, showing that teams are persistently and remarkably better at coordinating on efficient outcomes than individuals. All these results illustrate the potential effect that teams can have on alleviating coordination problems and call for further research on the endogenous implementation of teams in coordination problems.

Riedl et al (2016) allows for endogenous team formation through ostracism of agents, which cease to form part of the neighborhood. This allows agents to overcome the coordination problem by excluding other participants and leads to full efficiency. In a related study, Croson et al (2015) report small effects of exclusion of group members when it only affects the payoffs of the excluded agent, while this results in high efforts when exclusion entails the redistribution of foregone payoffs from the excluded agents among the rest of the group members. These two studies highlight the power of exclusion in enhancing efficiency. However, one may expect that the social costs of ostracism may be prohibitively high in many groups and societies, e.g., leading to a high employee turn-over rate in firms or the break-down of family businesses in which social ties are traditionally strong.

Our main research interest is to address whether milder forms of team formation can make a difference to the coordination problem. In the teams we consider, members can set common effort levels but they cannot isolate or exclude others. Our central research question is thus whether endogenous teams can alleviate the coordination problem in weakest-link games, without further requiring of ostracism. The following comment made by VHBB in their seminal paper would suggest an affirmative answer (p. 235): "If the players could explicitly coordinate their actions, the-real or imagined planner's decision problem would be trivial. […] each player should choose the maximum feasible action, $\hat{e}$. Moreover, a negotiated "pregame" agreement to choose $\hat{e}$ would be self-enforcing." We present the first experimental results testing this statement. In short, our results show that team formation is capable of (i) stopping the chain of downward adjustment towards risk-dominant equilibria, (ii) increase coordination levels in final rounds, although provision levels do not reach the Pareto-optimal values, as well as (iii) increase coordination levels compared to situations where team formation is not possible. Thus, we show that team formation can alleviate coordination failure, but also that it does not solve the coordination problem completely.

During our discussion below, we stress that the concept of Nash equilibrium yields multiple equilibria and that the refinement of Pareto-dominance is also not useful as it predicts the same outcome in all treatments with and without team formation, including riskier environments. In addition, Pareto-dominance predicts the best outcome in all cases, which is at odds with previous experimental results as well as with our experimental results. In order to rationalize our experimental results, we develop[2] Quantal Response Equilibrium (QRE) and Agent Quantal Response Equilibrium (AQRE) analyses for the VHBB and FIS weakest link games without and with team formation (for a general discussion, see McKelvey and Palfrey 1995, McKelvey and Palfrey 1998 or Goeree et al. 2016). These concepts can be used as refinement criteria and predict different outcomes with and without team formation, which we can test with our data. For small deviations from an assumption of perfect rationality, the equilibrium is the worst outcome without team formation and the Pareto superior outcome with team formation. For agents with bounded rationality, predictions support that team formation increases provision levels, but does not solve the coordination problem, as provision falls short of the Pareto-optimal levels. Our experimental results are consistent with the latter.

The rest of the paper is organized as follows: Section 2 describes the two weakest-link games considered, with and without team formation, and the associated payoff tables used in our experiments. Section 3 outlines the details of our experiments and section 4 presents and discusses

[2] Although Goeree and Holt (2005) use the QRE analysis developed in Anderson et al. (2001) to study experimental data from a weakest-link game with a continuous action space and a maximum of 3 players, to our knowledge, no previous paper has used the QRE to analyze a discrete weakest-link game, or the AQRE to analyze a multi-stage weakest-link game.

our results. Section 5 offers a theoretical analysis of the weakest link game, with and without team formation, using the QRE and AQRE concepts, and presents our estimations based on these concepts. Section 6 concludes.

2. THE COORDINATION GAMES

We consider separately decision settings in which individuals take individual decisions – no teams – and settings in which individuals can form teams, focusing in this section on Nash and Subgame Perfect Equilibria in pure strategies. An extension to a particular form of mixed strategies is introduced later (QRE and AQRE).

2.1. No Team Formation

We follow the mainstream of the experimental literature and consider the weakest-link game based on a simple linear payoff function of individual i:

$$\Pi_i^V\left(e_i, e_{-i}\right) = be^{min} - ce_i + K \text{ with } e^{min} = min\left\{e_1, e_2, \dots, e_n\right\}, \quad (1)$$

where n is the number of players; K is a constant scale parameter; b is a benefit parameter and c a cost parameter, with $b>0$ and $c>0$; e_i is the contribution level of individual i, and e_{-i} is the vector of contribution levels of all other players except i. For positive Nash equilibrium provision levels, we need to assume $b > c$. Following VHBB, we assume a discrete action space with 7 provision levels, $e_i = \{1,2,3,4,5,6,7\}$ and let the number of players be $n = 8$. Moreover, as VHBB, we assume $b = 20$, $c = 10$ and $K = 60$. This results in the canonical payoff matrix introduced by VHBB presented in Table 1. In their terminology, which we henceforth use, choosing a contribution level means choosing a number.

In Table 1, a player can choose any number between 1 and 7 as listed in the first column. The payoff, which this player obtains for a given number, depends on the smallest number chosen among all players, i.e., the minimum number. For instance, if a player chooses the highest number 7, she will earn 130 if all players choose 7. However, if the lowest number chosen by others is 6, she will earn only 110. Other combinations have a similar interpretation.

Table 1: VHBB Payoffs

Number you choose	Smallest number chosen by any participant in your group (including yourself): 7	6	5	4	3	2	1
7	130	110	90	70	50	30	10
6		120	100	80	60	40	20
5			110	90	70	50	30
4				100	80	60	40
3					90	70	50
2						80	60
1							70

Source: Van Huick et al (1990), Payoff Table A, p. 232, all entries multiplied by 100.

All Nash equilibria lie on the diagonal, and all players choosing 7 is the Pareto-dominant Nash equilibrium in this game. In a given row, all entries to the right of the diagonal entry imply a lower payoff to player *i*, as other players choose a lower number than player *i*. The larger the difference between the own number e_i and the minimum number of all others e_{-i}^{min}, the larger will be the loss compared to $e_i = e_{-i}^{min}$. Only for $e_i = 1$, $e_{-i}^{min} < e_i$ is not possible and hence player *i* is sure to receive a payoff of 70. Moreover, the minimum payoff over all $e_{-i}^{min} < e_i$ decreases with the minimum number chosen by player *i*, e_i. The minimum is 70 for $e_i = 1$ and it decreases to 10 for $e_i = 7$. Furthermore, in a given column, any number e_i, which does not match e_{-i}^{min}, also implies a loss. Altogether, this proves that $e_i = e_{-i}^{min}$ is a best reply to e_{-i}^{min}, i.e., $e_i^* = e_i(e_{-i}^{min})$ and hence by symmetry that in any Nash equilibrium $e_i^* = e_j^*$ for all $i, j \in N$, $i \neq j$ must hold.

In addition to the classical VHBB payoffs, we investigate the weakest-link game introduced by FIS, which is displayed in Table 2. The payoff for all $e_{-i}^{min} < e_i$ is zero and hence much lower than in Table 1. That is, the payoff function is a piecewise function given by

$$\Pi_i^F\left(e_i, e_{-i}\right) = be^{min} - ce_i + K \text{ if } e_i = e^{min} \text{ and } \Pi_i^F\left(e_i, e_{-i}\right) = 0 \text{ otherwise.} \quad (2)$$

Thus, compared to Table 1, coordination failure entails a larger loss in Table 2. For this reason, one could also view Table 2 as a “riskier weakest-link game” than Table 1. Except for this difference, the parameter values as well the action space are the same as in Table 1. The predictions for Table 2 are the same as in Table 1: there are 7 Nash equilibria along the diagonal and all players choosing number 7 is the Pareto-dominant Nash equilibrium.

Table 2: FIS Payoffs

		Smallest number chosen by any participant in your group (including yourself)						
		7	**6**	**5**	**4**	**3**	**2**	**1**
Number you choose	**7**	130	0	0	0	0	0	0
	6		120	0	0	0	0	0
	5			110	0	0	0	0
	4				100	0	0	0
	3					90	0	0
	2						80	0
	1							70

Source: Feri et al (2010), Table 1, Panel B, p. 1895.

In both tables, applying the maximin criterion of choosing the strategy that maximizes the minimum payoff would induce players to choose number 1, as it guarantees the largest payoff in the worst possible case. However, this yields the least efficient equilibrium. FIS point out that Table 2 keeps the property of Pareto-ranked equilibria but reinforces the attraction of the maximin criterion as a selection device, as any number greater than 1 can lead to a payoff of zero. Their experimental results, and our experimental results and our theoretical analysis in section 5.1 confirm their intuition. Thus, the FIS-payoffs provide a stronger test of the relative importance of payoff dominance versus taking a secure action.

2.2 Endogenous Teams

We consider a simple model of endogenous team formation in a two-stage game.[3] In stage 1, all individuals in a population decide whether to join a team S, $S \subseteq N$. In stage 2, all players choose their provision levels, i.e., their number, simultaneously. Within the team, we consider the following procedure. All s team members in S $(s \leq n)$ make simultaneously a proposal for a number, which, if adopted, will be implemented for the entire team in stage 2. Among all s proposals e_i^P, the minimum is adopted for the team, $e_S = min\{ e_1^P, ..., e_s^P \}$. All outsiders $j \notin S$

3 For an overview of team formation games, commonly called coalition formation games, see for instance Bloch (1997) and Yi (2003). For a theoretical discussion of coalition formation in the weakest-link game, see Caparrós and Finus (2020).

freely choose their individual number e_j. The outcome of stage 2 is $e_{min} = \{ e_S, e_j \} \; \forall j \notin S$. If S is empty or contains only one member, i.e., no team has formed in stage 1, all players choose their provision levels like in the game without team formation.

Choosing the minimum of the proposals for team members entails unanimity voting.[4] It is easy to show that for this voting rule, revealing true preferences is a dominant strategy (Moulin 1991). We chose this assumption because we expect that this assumption makes it attractive to join the team, which is the focus of our analysis. Nevertheless, it is clear that as long as the grand team does not form, and hence there are some outsiders left when entering stage 2, the team cannot control the provision level by outsiders. They must fear that any provision level e_S above 1 may not be matched by outsiders. However, as long as $s \geq 2$, the risk for the team of any outsider $j \notin S$ choosing $e_j < e_s$ is lower, as the team acts de facto as one player, and thus there are less players. By symmetry, also the risk for every outsider j that any other player chooses a lower provision level $e_{-j} < e_j$ is lower than without team formation.

Solving the game via backward induction, we start analyzing stage 2. For a grand team, where all group members decide to play in a team, one could assume that they will choose number 7, which maximizes payoffs. As there is no outsider left, and given unanimity voting, there is no risk in proposing 7. However, for any team size which is smaller than the grand team, all numbers between 1 and 7 are Nash Equilibria in the second stage. This multiplicity of second stage equilibria implies that theoretical predictions for stage 1 lack predictive power. But even if one imposes additional selection criteria for stage 2, like Pareto-dominance, predictions about stage 1 are not sharp, as teams of any size implementing 7 are subgame-perfect equilibria.

3. EXPERIMENTAL DESIGN

Subjects participated in one of four alternative treatments in a 2x2 between-subjects design varying the possibility to form teams as well as the payoff table for the coordination game (see Table 3).

---

4 Our team formation game has been designed with a high degree of consensus. Membership and the choice of the team number are taken by unanimity. In terms of membership, this resembles features of the exclusive membership Γ-Game of Hart and Kurz (1983) or the sequential move unanimity game by Bloch (1995), as discussed in Finus and Rundshagen (2008). In terms of the choice of the team number, this resembles the smallest common denominator proposal in bargaining games. Moulin (1994) has shown that this "conservative mechanism" is strategy-proof and hence leads to unbiased proposals.

For the VHBB payoffs (Table 1) this gives rise to the *Baseline* and *Team* treatment and for FIS payoffs (Table 2) this gives rise to the *Risk* and *Risk-Team* treatment. The experiment comprised 20 rounds, which are divided into two parts (Part 1: rounds 1-10 and Part 2: rounds 11-20). Subjects learned the details of Part 1 at the beginning, and after the completion of Part 1 were introduced to Part 2. In treatments *Baseline* and *Risk*, all subjects played the coordination game with payoffs in Tables 1 and 2, respectively, for 20 rounds.[5] In contrast, in treatments *Team* and *Risk-Team* subjects started by playing 10 rounds without team formation, followed by 10 additional rounds where subjects had the possibility to form teams. Including Part 1 without the possibility to form teams was important because we are interested in how institutional changes affect behavior in a given cohort, given that there is a history where subjects have experienced the coordination problem before having the option to form teams. In addition, Part 1 provides an initial measure of coordination failure in the absence of team formation.

Table 3: Summary of Experimental Sessions

Treatment	Payoff Function	Team, Part 1 (Round 1-10)	Team Part 2 (Round 11-20)	Number of subjects	Number of groups
Baseline	Van Huick et al. (1990)	No	No	64	8
Team	Van Huick et al. (1990)	No	Yes	72	9
Risk	Feri et al. (2010)	No	No	72	9
Risk-Team	Feri et al. (2010)	No	Yes	64	8
				272	17

Instructions were read aloud in order to ensure that details of the experiment were public information. The language used in the experiment was neutral. Subjects were randomly and anonymously assigned to groups of 8 people. Groups remained fixed for the duration of the experiment. Before making decisions in Part 1 and Part 2 in all treatments, subjects answered quizzes to check their understanding of the game. See Supplementary Material II for instructions.

[5] For consistency with treatments with team formation, the instructions for treatments without team formation also included a Part 1 and a Part 2. Subjects were told at the end of Part 1 that the game would continue for 10 more rounds in Part 2.

In each round in which subjects were not allowed to form teams, subjects were confronted with the sole decision to simultaneously choose a number out of 1, 2, 3, 4, 5, 6, or 7. At the end of each round, in each group, subjects saw an information screen summarizing the number chosen by the subject, the minimum number chosen in her group, her earnings for that given round, and her cumulative earnings.

In rounds in which subjects were allowed to form teams, decisions were structured according to 4 phases to ease the understanding of the game. In phase 1, all members of a group decided if they wanted to play as an individual or in a team. If a subject decided to play as an individual, her next decision was in phase 4. If she decided to play in a team, and if at least another group member decided to play in a team, all team members moved to phase 2. At the beginning of phase 2, all team members were informed about how many subjects decided to join the team and were asked to confirm their membership. If at least one team member did not confirm her membership, the team dissolved and everyone moved to phase 4. If all team members confirmed membership, team members moved to phase 3. In phase 3, each team member suggested a number between 1 and 7 to be implemented by the team in phase 4. The smallest of these numbers was automatically implemented by the team in phase 4. Notice that this implies that, irrespective of whether a subject joined the team, she could not be forced to play a number above her own choice.[6] Lastly, in phase 4, if a team had formed, the team number selected in phase 3 was automatically and uniformly implemented by each team member. Any individual who was not a member of the team chose independently and freely a number between 1 and 7, without any knowledge about the number chosen by the team. At the end of each round (including 4 phases), all subjects saw an information screen summarizing the own number played, the minimum number chosen in her group (minimum of team or no team members), her earnings for this round, her cumulative earnings. In addition, all subjects saw whether a team had formed and, if a team formed, the size of the team and the number chosen by the team.

All sessions were conducted at the University of Innsbruck EconLab. The experiments used z-Tree (Fischbacher, 2007) for programming and ORSEE (Greiner, 2015) for subject recruitment. Sessions lasted for about an hour and participants earned on average 13.28 Euros.

[6] See footnote 4.

4. EXPERIMENTAL RESULTS

We first analyze whether teams are initiated and confirmed. We then analyze whether team formation increases provision levels, by comparing average numbers and minimum numbers with and without team formation in Part 2. Finally, we analyze whether team formation has an impact on the evolution of provision levels over time by comparing the trend of average and minimum numbers.

4.1 Team Formation

This section analyzes the sizes of the teams initiated and eventually confirmed. We consider Part 2 of the experiment (rounds 11-20) for the two treatments where teams can form. We first focus on those instances for which at least two subjects proposed to form a team in phase 1 of a round (*initiated* teams) and analyze whether those subjects who proposed a team unanimously confirm their membership in phase 2 of that round (*confirmed* teams). Table 4 provides an overview of results. In treatment *Team,* 90 teams were initiated, which implies that teams were initiated in every round and in every group (100 percent). Of those 90 initiated teams 80 teams were confirmed, which gives a confirmation rate of 88.89 percent. In treatment *Risk-Team*, in 78 out of 80 possibilities a team was initiated (97.5 percent) of which 48 were confirmed, which corresponds to a confirmation rate of 61.54 percent. While the rate of teams initiated is not significantly different between treatments (Mann-Whitney U Test, p=0.1325), the confirmation rate is statistically higher in *Team* than in *Risk-Team* (Mann-Whitney U Test, p=0.0000).

In both *Team* and *Risk-Team*, the vast majority of teams confirmed are grand teams that contain all eight subjects in a group. The absolute number of grand teams is very similar in the two treatments, 41 grand teams in *Teams* and 45 in *Risk-Teams*. However, these absolute numbers represent different frequencies over the total number of teams initiated. The grand team constitutes 51.25 percent in *Team* of the total teams confirmed (i.e., 41 out of 80) and 93.75 percent in *Risk-Team* (i.e., 45 out of 48). This is because in *Team* the size of teams confirmed is diverse while in *Risk-Team* there are only three instances of confirmed teams smaller than the grand team. For the grand teams, confirmation rates are similar in *Team*, 93.18, and *Risk-Team*, 97.83 percent. However, they differ for teams that contain less than eight members. In *Team* the confirmation rate of initiated teams smaller than the grand team is above 65 percent in all cases, while the

Table 4a: Initiated and Confirmed Teams across Treatment "Team"

	Initiated Teams	Confirmed Teams	Confirmation Rate (%)	Percentage of Confirmed Teams by Size
Total	90	80	88.89	100
Two Members	1	1	100	1.25
Three Members	8	8	100	10
Four Members	3	2	66.67	2.5
Five Members	5	4	80	5
Six Members	17	14	82.35	17.5
Seven Members	12	10	83.33	12.5
Eight Members	44	41	93.18	51.25

Table 4b: Initiated and Confirmed Teams across Treatment "Risk-Team"

	Initiated Teams	Confirmed Teams	Confirmation Rate (%)	Percentage of Confirmed Teams by Size
Total	78	48	61.54	100
Two Members	3	0	0	0
Three Members	2	0	0	0
Four Members	2	0	0	0
Five Members	8	1	12.5	2.08
Six Members	6	0	0	0
Seven Members	11	2	18.18	4.17
Eight Members	46	45	97.83	93.75

Note: The table shows absolute and relative numbers of initiated and confirmed teams broken down by team size. In treatment *Team* there are 9 groups observed in 10 rounds in Part 2 such that there is a maximum of 90 instances where teams can be initiated and confirmed. In treatment *Risk-Team* there are 8 groups observed in 10 periods making a maximum of 80 instances where teams can be initiated and confirmed. The confirmation rate for each team size is the percentage of successfully confirmed teams relative to the number of initiated teams within each class. The percentage of confirmed teams by size measures the number of confirmed teams for a given size relative to the total number of confirmed teams.

corresponding confirmation rate in *Risk-Team* is below 20 percent. Thus, participants in *Team* are more likely to accept the risk of not all group members joining the team, whereas participants in *Risk-Team* prefer to dissolve the group if they realize that not all other group members are playing in the team. Indeed, the difference between the average size of confirmed teams in *Team* (6.7 members (SD=1.72)) and *Risk-Team* (7.9 (SD=0.47)) is statistically significant (Mann-Whitney U Test, p=0.0000). Our observations are summarized in Result 1 below.

Result 1: *Individuals use the opportunity to form teams: they initiate and confirm teams in Team and Risk-Team. The rate of teams initiated is similar in both treatments. Out of those, the confirmation rate is smaller in riskier environments (FIS payoffs), where predominantly only the grand team is confirmed.*

Result 1 is further substantiated by an analysis of the evolution of team formation over rounds. Figure A1 in Supplementary Material I shows the relative frequencies (in percent) of different sizes of teams, in addition to the numbers chosen by the teams and the resulting minimum numbers in treatment *Team* (Panel A) and *Risk-Team* (Panel B), broken down by rounds. The distribution of different team sizes in both treatments *Team* and *Risk-Team* are unimodal with the majority of the distribution mass coming from grand teams in all rounds and with a stronger modality in *Risk-Team*.

A Spearman's rank order correlation shows a significant negative correlation between the number of confirmed teams and rounds in treatment *Team* (ρ=-0.69, p=0.0283) and no significant correlation in *Risk-Team* (ρ=0.36, p=0.3059). The negative correlation in *Team* is even stronger for the number of grand teams confirmed over rounds (Spearman rank order correlation: ρ=-0.76, p=0.0102) whereas it is significantly positive in *Risk-Team* (Spearman rank order correlation: ρ=0.87, p=0.0009). The number of confirmed teams with fewer than eight members over rounds is constant in *Team* (Spearman rank order correlation: ρ=-0.08, p=0.8307) and negative in *Risk-Team* (Spearman rank order correlation: ρ=-0.68, p=0.0294). Thus, the decreasing number of confirmed teams over time in *Team* originates from a downward trend in the number of confirmed grand teams. In *Risk-Team*, the constant relationship between the number of confirmed teams and rounds masks two opposing trends: an increasing number of confirmed grand teams over rounds and a decreasing number of confirmed teams with fewer than eight members.

4.2 Provision Levels

In order to address the impact of team formation, in terms of average contributions and in terms of equilibrium provision levels, we investigate differences in two main output variables between treatments with team formation, namely *average numbers* and *minimum numbers*.[7] All analyses are conducted at the group level, where each group of 8 subjects is treated as an independent unit

[7] For simplicity, we use "minimum numbers" instead of "average minimum numbers" when we report on averages over all groups.

of observation. The minimum number in a round measures the group output level and influences the payoff that subjects receive in this particular round. The average number in a round is a measure for the numbers chosen by all subjects in this round. By construction, the minimum number is weakly smaller than the average group number, and for groups with perfect coordination the two numbers coincide. The average and minimum numbers across all groups in each round are presented in Figure 1- Panel A and Figure 1 – Panel B, respectively.[8]

As shown in Table 5, average numbers and minimum numbers in Part 2 are significantly higher in treatment *Team* than in *Baseline*. Although both average numbers and minimum numbers are higher in *Risk-Team* than in *Risk,* these differences are not significant.[9] The comparison between treatments provides evidence on the positive impact of team formation on provision levels for the VHBB payoff. However, even with team formation, minimum numbers fall short of the Pareto-optimal level 7. It is also interesting to observe that grand teams perform equally well in both treatments, exhibiting the minimum number of 5.63 (SD 1.59) in *Team* and 5.51 (SD 2.53) in *Risk-Team*, (Mann-Whitney U test p=0.0656). This is not the case for teams of smaller size.

The following result summarizes the discussion above:

Result 2: *Average numbers and minimum numbers are significantly higher with the VHBB payoff when team formation is possible. With FIS payoffs average numbers and minimum numbers are higher when team formation is possible but not significant. Overall, provision levels do not reach the Pareto-optimal values.*

That is, team formation alleviates the coordination problem but does not solve it.

---

8 The average and minimum numbers in all twenty rounds separated by groups and by treatments are shown in Figures A2-A5 (average numbers) and A6-A9 (minimum numbers) in Supplementary Material I. A test of significance of differences between Parts 1 and 2 for the different treatments, based on a Wilcoxon Signed-Rank Test, can be found in Table A.1 in Supplementary Material I.

9 The lack of significant differences is partly driven by an outlier group in treatment *Risk* that is coordinating on the payoff-dominant equilibrium in all 20 rounds. Excluding this group, minimum numbers in part 2 in treatment *Risk-Team* are significantly higher than in *Risk* (p= 0.027), while there is no significant difference in average numbers (p= 0.875).

Figure 1- Panel A: Average Numbers across Rounds

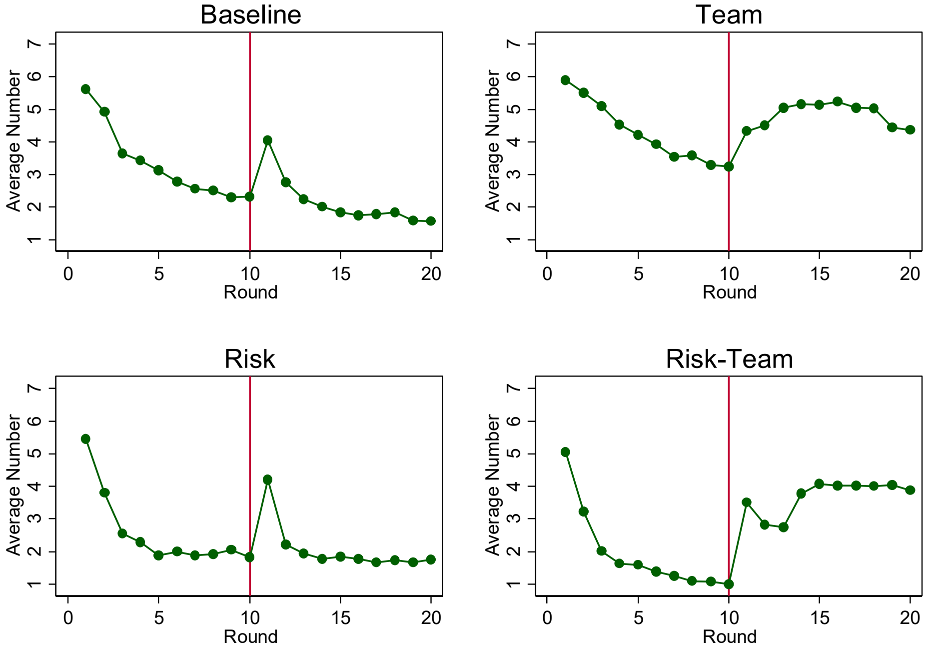
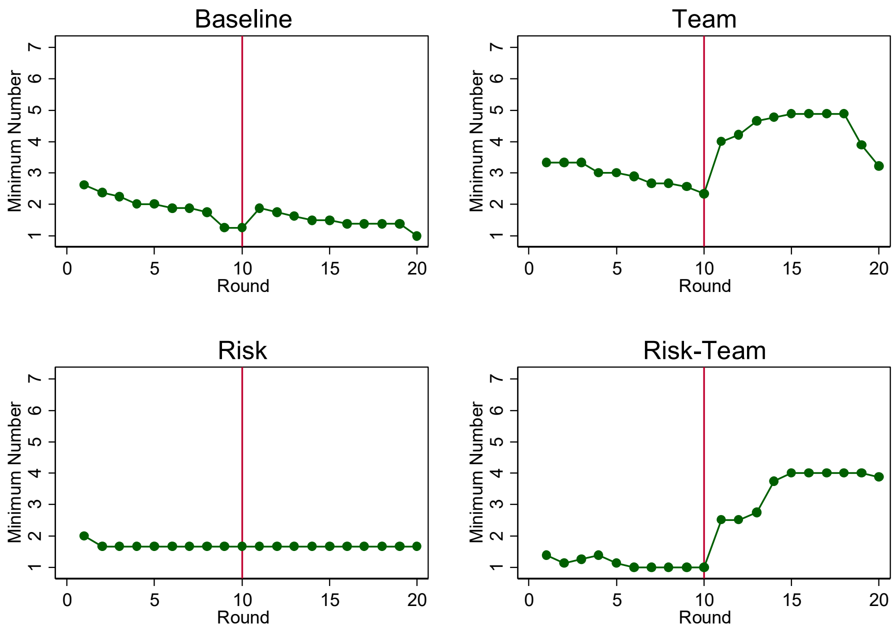


Figure 1 – Panel B: Minimum Numbers across Rounds



Note: The straight vertical line at round 10 separates rounds 1-10 of Part 1 from rounds 11-20 of Part 2.

Table 5: Comparison between Treatments of Average Numbers and Minimum Numbers in Part 2

	Baseline	***Team***	Mann-Whitney U Test(3)	***Risk***	***Risk-Team***	Mann-Whitney U Test
Average(1) Number in Part 2	2.145	4.832	** (0.0209)	2.056	3.688	(0.8471)
Minimum(2) Number in Part 2	1.475	4.433	** (0.0113)	1.667	3.538	(0.1348)

Notes: (1) Average Number: arithmetic mean of average numbers over all rounds in part 2 over all groups in the same treatment. (2) Minimum number: arithmetic mean of minimum numbers over all rounds in part 2 over all groups in the same treatment. (3) Significance of differences between parts, based on a Mann-Whitney U Test. Significance at the 1 percent (***), 5 percent (**) and 10 percent (*) level. P-values are given in parentheses

4.3 Dynamics

This section analyzes the effect of team formation on the trends of output variables. We explore the dynamics by analyzing the trend of average numbers and minimum numbers throughout rounds within Part 1 and Part 2, using the Jonckheere-Terpstra test[10] for ordered alternatives. The impression of a decreasing trend of average numbers throughout rounds 1-10 as observed in Figure 1 - Panel A is supported by the result of a Jonckheere-Terpstra test. There is a statistically significant trend of lower average numbers in Part 1 in the game with no team formation in all treatments (p=0.0000 in *Baseline*; p=0.0000 in *Team*; p=0.0000 in *Risk* and p=0.0000 in *Risk-Team*). This is in line with the downward sloping trend commonly observed in coordination experiments without team formation (Van Huick et al 1990; Feri et al 2010 and Riedl et al. 2016). Moreover, the trend of average numbers across rounds 11-20 in Part 2 is different between treatments with and without team formation. While a negative trend is observed in Part 2 in the treatments without team formation (p=0.0000 in *Baseline* and p=0.0000 in Risk), there is no

---

10 The Jonckheere-Terpstra test for a decreasing trend tests the null hypothesis that average numbers are equal in all rounds against the alternative hypothesis that average numbers are equal or decreasing over rounds. In particular, for Part 1, if μ_i denotes the average number in round i then H0: $\mu_1=\mu_2=\ldots=\mu_{10}$ and HA: $\mu_1\geq\mu_2\geq\ldots\geq\mu_{10}$ with at least one strict inequality (Lunneborg 2005). Alternatively, the test can also be specified for an ascending trend.

statistically significant trend in the treatments with team formation (p=0.6797 in *Team* and p=0.5000 in *Risk-Team*). Thus, team formation has a stabilizing effect on average numbers.[11]

Similar comments apply to the development of minimum numbers. In Part 1, a significant descending trend of minimum numbers throughout rounds 1-10 is observed in treatments *Baseline*, *Team* and *Risk-Team*. A Jonckheere-Terpstra test for a descending ordered alternative hypothesis yields p=0.0003 in *Baseline*, p=0.0311 in *Team*, p=0.1956 in *Risk* and p=0.0066 in *Risk-Team*. Note that the initial minimum number in round 1 in treatment *Risk* (1.7) is already close to the lowest possible number which makes the possibility for a descending trend across rounds in Part 1 unlikely.[12] In Part 2, Figure 1–Panel B shows that treatments with and without team formation exhibit different patterns of minimum numbers. Minimum numbers are decreasing throughout rounds in treatment *Baseline*, show no trend in treatment *Team* and *Risk* and increase across rounds in treatment *Risk-Team*. In treatment *Risk* minimum numbers are again close to the lowest possible number in all rounds of Part 2 such that a negative trend is unlikely to emerge. A Jonckheere-Terpstra test for a descending ordered alternative hypothesis for minimum numbers throughout all rounds in Part 2 yields p=0.0053 in *Baseline*, p=0.5258 in *Team*, p=0.5000 in *Risk* and p=0.9313 in *Risk-Team*. In *Risk-Team* the alternative hypothesis of an ascending order of minimum numbers is not rejected (p=0.0687). Result 3 summarizes our observations.

> **Result 3:** *Team formation stops the downward trend of average and minimum numbers over rounds for VHBB-payoffs. In risky environments with FIS-payoffs, team formation increases average and minimum numbers.*

Comparing the average and minimum numbers in the final rounds of Part 1 and Part 2 yields equivalent results. In *Team*, average and minimum numbers are not significantly different in

---

11 A Friedman test was conducted as a robustness check for the results of the Jonckheere-Terpstra trend test, providing the same results. There is a significant difference among average numbers in Part 1 in all treatments (X^2=61.8136, p=0.0000 in *Baseline*; X^2=70.5818, p=0.0000 in *Team*; X^2=41.2303, p=0.0000 in *Risk* and X^2=43.5818, p=0.0000 in *Risk-Team*). Moreover, there is a significant difference among average numbers in Part 2 in treatments *Baseline* and *Risk* (X^2=43.0977, p=0.0000 in *Baseline*; X^2=26.6061, p=0.0016 in *Risk*) while the null hypothesis of equal average numbers across rounds in Part 2 is not rejected in treatments *Team* and *Risk-Team* (X^2=13.7758, p=0.1305 in *Team* and X^2=4.6364, p=0.8648 in *Risk-Team*).

12 There was one group in treatment *Risk* which coordinated on the highest possible number in all rounds 1-20 (See Figure A3, Group *Risk_5* in the Supplementary Material I). Excluding this outlier group from the analysis does not change qualitative results on trend behavior but shifts average numbers and minimum numbers downwards.

rounds 10 and 20 (p=0.4156 for average numbers and p=0.3221 for minimum numbers), stopping the downward trend observed in *Baseline,* where average numbers are significantly lower in round 20 compared to round 10 (p=0.0350). In *Risk-Team*, both average numbers as well as minimum numbers are significantly higher in round 20 relative to round 10 (p=0.0474), whereas in Risk there are no significant differences in average (p=0.2587) or minimum numbers between rounds 10 and 20.

5. (AGENT) QUANTAL RESPONSE EQUILIBRIUM

From the results in Section 4 it is clear that the refinement concept of Pareto-dominance of Nash equilibria is not a good predictor of our experimental result. Therefore, in this section we propose Quantal Response Equilibrium (QRE) and Agent Quantal Response Equilibrium (AQRE) analyses. In section 5.1, we introduce these concepts and derive theoretical predictions. In section 5.2, we test these theoretical predictions, provide estimations based on our experimental data and develop additional estimation-based predictions.[13]

5.1 Theoretical Predictions

The QRE is a Nash equilibrium in mixed strategies based on a probabilistic choice function to model decision making with payoff sensitive errors (McKelvey and Palfrey 1995), and the AQRE is an extension of the QRE to games with more than one stage (see McKelvey and Palfrey 1998). The basic idea on which the QRE and the AQRE are built is that decisions are stochastic and all actions have a non-zero probability of being selected (Goeree et al. 2016). However, the probability of choosing non-optimal actions is inversely related to the loss induced. In other words, players are better-response agents, not best response agents. The sensitivity of players to errors is measured by an "error parameter", λ. Larger values of λ imply larger sensitivity to errors and make non-optimal choices less likely. For $\lambda = 0$, choices are purely random and for $\lambda \to \infty$ choices are (almost) perfectly rational, in the sense that options with larger expected payoffs are selected with probability close to one.

[13] We distinguish between theoretical predictions, valid for any value of the parameter λ defined below, and estimation-based predictions, which are only valid for the estimated parameters.

As most of the literature, we use a logit equilibrium specification for our game. Without team formation, and with reference to our specific setting, the equilibrium is the solution to the following system of equations:

$$\sigma_{ij}(\lambda) = \frac{e^{\lambda V_{ij}(\sigma)}}{\sum_{i=1}^{7} e^{\lambda V_{ik}(\sigma)}} \text{ for all } i \in \{1,2,...,8\},\ j \in \{1,2,...,7\} \tag{3}$$

where σ_{ij} is the probability that agent *i* selects the provision level (i.e., number) *j*, σ is the set of all mixed strategies over all players (i.e., probabilities overall actions and all players) and V_{ij} is the expected payoff of agent *i* when she selects number *j*. The logit equilibrium correspondence includes the solutions for all possible values of λ and is defined as

$$\sigma^* : \lambda \rightarrow \left\{ \sigma : \sigma_{ij}(\lambda) = \frac{e^{\lambda V_{ij}(\sigma)}}{\sum_{i=1}^{7} e^{\lambda V_{ik}(\sigma)}} \ \forall\, i,j \right\}. \tag{4}$$

Note that the expected payoff V_{ij} depends on σ. Choosing 1 gives a certain value of 70, but the payoffs associated with choosing 2 depends on the probability that any other player chooses 1, as the player only defines the minimum if no other player chooses 1. The same logic is applied to calculate the remaining payoffs and associated probabilities (see Supplementary Material III.1 for details).

We find the logit correspondence numerically for both payoff functions (VVHS and FIS), focusing on symmetric equilibria (Turocy, 2010). As in all games, for $\lambda = 0$ there is a unique logit equilibrium close to the "centroid" of the game, where all strategies are adopted with equal probability. This entails that all numbers between 1 and 7 are played with equal probability. One can then trace out a principal branch of the logit correspondence for progressively higher values of λ until $\lambda \rightarrow \infty$. The limit point of the principal branch as λ approaches infinity is called the logit solution of the game. When there is a unique branch that connects the centroid to exactly one Nash equilibrium, as in most simple games, and in particular in the weakest-link game, this can be seen as a strong refinement (McKelvey and Palfrey 1995; Goeree et al. 2016).

For the VHBB and the FIS payoffs, the logit equilibrium when $\lambda \rightarrow \infty$ implies that 1 is played with a probability close to one. This result is closely related to risk dominance and to the potential function proposed by Monderer and Shapley (1996), as discussed in detail in Goeree and Holt (2005). Furthermore, for relatively small values of λ, above 0.4519 for the VVHS payoffs and above 0.2479 for the FIS payoffs, the logit equilibrium already yields a probability larger than 0.9999 of playing 1. That is, convergence to the worst possible outcome occurs faster under the FIS- than VVHS-payoffs, confirming the intuition discussed in FIS that the payoffs in Table 2 favor the “secure” action of choosing 1.

For team formation with two stages, we apply the AQRE (McKelvey and Palfrey 1998). A behavioral strategy is an AQRE if each player *i* is choosing her best response at every information set, taking σ_{-ij} and the error structure associated with the logit equilibrium as given. Furthermore, any limit point of a sequence of logit AQRE when $\lambda \to \infty$ corresponds to a sequential equilibrium of the game (Goeree et al. 2016). Basically, the solution is obtained via backward induction. More precisely, to calculate the AQRE one needs to calculate the probabilities of all actions available at each information set, conditional on arriving at a particular information set and based on continuation values. The logit AQRE correspondence σ^* is then defined as the mapping from $\lambda \in [0,1)$ to the set of logit AQRE behavioral strategies:

$$\sigma^* : \lambda \to \left\{ \sigma : \sigma_{ij}(\lambda) = \frac{e^{\lambda V_{ijk}(\sigma)}}{\sum_{a_j \in A(h_i^k)} e^{\lambda V_{ijk}(\sigma)}} \; \forall \, i,j,k \right\} \tag{5}$$

where $A(h_i^k)$ is the finite set of actions a_j available to agent *i* at information set h_i^k. As before, details on how the payoffs and associated probabilities are calculated can be found in Supplementary Material III.2. The main difference is that now, while calculating these probabilities, one needs to take into account that the number of independent players varies between 1 if the grand team forms and 8 if no team forms. That is, the larger the team the smaller the number of outside players to be considered when calculating the expected payoff associated with selecting one particular number between 1 and 7. Essentially, from the perspective of the team as well as from the perspective of all single players, team formation implies that the probability of other players choosing a provision level below the own provision level is reduced, and hence the risk of receiving a low payoff is reduced. In sum, risk decreases with the size of the team and is zero if the grand team forms.

At the information set of the first stage, there are only two actions available to each player (join the team or remain a singleton) and the payoffs associated with each action depends on the expected payoffs in the second stage, which in turn depends on the size of the team emerging from the first stage (see Supplementary Material III.2 for details).

The analysis based on the (A)QRE allows us to write the following Testable Predictions:

Testable Predictions *Consider the weakest-link games introduced in section 2, the VHBB payoff function (1) and the FIS payoff function (2), with b=20, c=10, K=60, n=8 and* e_i*={1,..,7}. Correspondences (4) and (5) imply for the QRE and the AQRE the following:*

i) Without team formation, for any λ*, minimum numbers are below or equal to 1.37 and average numbers below or equal to 4. Both numbers converge to 1 for* $\lambda \to \infty$.

ii) With team formation, for any λ*, the probability of joining the team is larger or equal to 0.50. When intermediate teams are formed, minimum numbers are below 7. Moreover, for* $\lambda \to \infty$*, the grand team and a minimum number of 7 are obtained with a probability that tends to 1.*

iii) Minimum numbers are larger with team formation than without for any $\lambda > 0$.

Proof: Supplementary Material III.

These Testable Predictions are valid for any value of λ. Hence, experimental data that differ significantly from these predictions would refute the (A)QRE models in our setting[14]. The next section will show that this is not the case.

Our Testable Predictions also show that (almost) perfectly rational agents, i.e. when $\lambda \to \infty$, coordinate on the worst possible outcome if there is no team formation, while with team formation they form the grand team and coordinate on the best possible equilibrium provision. That is, (almost) perfect rationality is a curse for the basic coordination game, but it may be a blessing once team formation is possible. This is consistent with the intuition in the VHBB quote in the introduction. However, for agents with bounded rationality, there is no guarantee that team formation will solve the coordination problem as, depending on the value of λ, the probability of joining a team can vary between 0.50 and 1.00. In addition, intermediate coalitions choose on

[14] As shown by Haile et al (2008), introducing sufficient flexibility a structural QRE and AQRE model can rationalize almost any behavior. However, this is not the case for our logit QRE and AQRE and its Independence of Irrelevant Alternatives assumption. For an approach using a flexible (heterogeneous) QRE and AQRE, see Rogers et al. (2009).

average values below 7, and even the grand team can choose values between 4 and 7. Hence, our hypothesis is that team formation will alleviate the coordination problem but will not solve it completely in the light of imperfect rationality, which is in line with the treatment effects presented in Section 4.

5.2 Estimation and Results

As we are interested in equilibrium behavior, we focus on the behavior observed in the last five rounds of the game (rounds 16 to 20). For the case without team formation, the log-likelihood function to be estimated is

$$log\,L(\lambda, f) = \sum_{i=1}^{n} \sum_{j=1}^{7} f_{ij}\, log(\sigma_{ij}^{*}(\lambda)) \tag{6}$$

where the observed empirical frequencies of strategy choices are denoted by f, and f_{ij} represents the number of observations of player i choosing j. The maximum-likelihood estimates are $\hat{\lambda} = arg\,max_{\lambda}\, log\,L(\lambda, f)$. For the case with team formation, the estimation strategy is basically the same (see Supplementary Material III.3 for details). As all players take decisions in both stages, we add the different components of the log-likelihood function. Standard errors are estimated in both cases using the bootstrapping method (Efron 1979; Train 2009).

The first two columns of Table 6 show the results for the logit QRE models estimated for the two treatments without team formation. As can be seen, the estimation of the parameter $\hat{\lambda}$ is significant in all cases. The last two columns report the results for the logit AQRE model estimated for both treatments with team formation. The estimations of $\hat{\lambda}$ are again significant.

Table 6: Estimation results for the logit QRE and AQRE models for rounds 16-20

	No team treatments (QRE)		**Team treatments (AQRE)**	
	Baseline	**Risk**	**Team**	**Risk-Team**
$\hat{\lambda}$	0.0870***	0.0527***	0.0324**	0.0898**
	(0.0242)	(0.0126)	(0.0129)	(0.0146)
Log-L	369.6219	223.6916	894.7407	532.0091
M	320	360	360	320

Note: Standard errors are shown in brackets; $\hat{\lambda}$: estimated λ; M: number of observations. Significance at the 10% (*), 5% (**) and 1% (***) level.

For the second stage, Table 7 shows the average and minimum numbers observed in rounds 16 to 20 as well as the estimation-based predictions obtained with the different models, which are obtained by using the estimated $\hat{\lambda}$-values shown in Table 6.

Table 7: Observed and estimation-based predicted average and minimum numbers for rounds 16 to 20

	Observed Data		(A)QRE predictions[1]	
	Average Number	Minimum Number	Average Number	Minimum Number
Baseline	1.7063	1.3000	1.7069 [1.3523-2.6241]	1.0009 [1.0000-1.0380]
Risk	1.7167	1.6667	1.4565 [1.0907-2.6029]	1.0000 1.0000-1.0025]
Team	4.8222	4.3556	3.1898 [2.5897-3.8324]	1.6026 [1.4432-1.8401]
Risk-Team	3.9906	3.9750	3.2260 [1.1300-4.5879]	3.2027 [1.0433-4.5599]

[1] Predictions using parameters estimated based only on data from the treatment. According to Table 6, we use: QRE with $\hat{\lambda}$ =0.0870 for Baseline and with $\hat{\lambda}$=0.0527 for Risk; AQRE with $\hat{\lambda}$=0.0324 for Team and with $\hat{\lambda}$=0.0898 for Risk-Team. 95% confidence intervals are shown in square brackets. Average and minimum numbers for a given treatment are the arithmetic means over all groups and all five rounds.

Without team formation, the experimental data is in line with our Testable Prediction (i). Observed average numbers are well below 4, and minimum numbers are below the benchmark of 1.37 for the *Baseline* treatment and slightly above this number for the *Risk* treatment. Estimation-based predictions, with $\hat{\lambda} = 0.0870$ for *Baseline* and $\hat{\lambda} = 0.0527$ for *Risk*, perform well for average numbers but are more pessimistic than the observed data regarding minimum numbers. Nevertheless, not surprisingly, the logit QRE predicts observed behavior far better than Pareto dominance, which would support provision levels of 7.

The second half of Table 7 shows the observed and the estimation-based predicted averages and minimum numbers with the logit AQRE models for the two treatments with team formation. In line with our Testable Prediction (iii), the estimation-based predictions shown in Table 7, as well as the observed results, imply an increase in minimum numbers compared to the case without team formation. This is also in line with the treatment effects observed for team formation and highlighted in Result 2. However, for both treatments, the estimation-based predictions for the

AQRE are more pessimistic than the behavior observed (although within the confidence interval for the Risk-Team treatment).

For the last five rounds, the observed share of implemented teams is 0.79 for the *Team* treatment, and 0.78 for the *Risk-Team* treatment. These shares are well above the minimum of 0.50 shown in our Testable Prediction (ii), and thus do not refute the AQRE model. However, again, estimation-based predictions are more pessimistic than the observed data for the Team treatment, as the predicted share is 0.53, with confidence interval [0.51-0.55], for $\hat{\lambda} = 0.0324$. For the Risk-Team treatment the predicted share is 0.88, with confidence interval [0.51-0.99], for $\hat{\lambda} = 0.0898$.

We now highlight the main results discussed above:

> **Result 4:** *Experimental results are consistent with the predictions valid for any λ detailed in our Testable Predictions. Estimation-based predictions (Table 7) are more pessimistic than the observed behavior for minimum numbers and in line for average numbers.*

From our Testable Prediction (ii) we know that if we assume (almost) perfect rationality, i.e., $\lambda \to \infty$, team formation was to solve the coordination problem, as all players would join the grand team and then select the highest number, 7. Not surprisingly, as subjects are far from perfectly rational in our experiment (estimated $\hat{\lambda}$ are clearly far below infinity; see Table 6), the prediction discussed at the end of section 5.1 is confirmed, namely that team formation contributes to alleviate the coordination problem, but cannot solve it as long as individuals make mistakes (i.e., are not perfectly rational).

6. CONCLUSIONS

This study provides a first experimental analysis of the potential of team formation in order to increase provision levels in weakest-link games in fixed groups. Teams facilitate subjects to voluntarily coordinate on their preferred contribution level, in a setting without the possibility of excluding neighbors. Our results show that even without exclusion possibilities, endogenous team formation within a group can alleviate the coordination problem, despite not achieving first-best outcomes. This is a remarkable result in terms of testing theory, which also has interesting policy implications.

From a policy perspective, this result suggests that in field settings where coordination failure is prevalent, team formation can be an alternative to harsh interventions entailing ostracism to group members or full exclusion. This conclusion is important as there are many situations in which exclusion is costly or simply impossible because it creates tensions among the members in a group (who may be involved also in other tasks than providing a public good for the group) or because of legal or physical restrictions. Milder interventions, in the form of providing the opportunity of forming teams, come at a cost of not reaching first-best outcomes, but this might be a reasonable price to pay in exchange for contained inter-group conflict.

We confirm previous literature showing that the concept of Pareto-dominance of Nash equilibria is not a good predictor to explain experimental results in weakest-link coordination games. In fact, the problem of multiplicity of Nash equilibria was only exacerbated in our analysis with team formation. Quantal Response and Agent Quantal Response Equilibria, allowing for small deviations from perfectly rationality, provided predictions with opposite behavior with and without team formation: (Almost) perfect rationality is a curse for the basic coordination game while it is a blessing once team formation is possible. When considering agents with bounded rationality, the models capture the observed behavior that team formation alleviates the coordination problem but does not solve it.

Acknowledgements: We are grateful to participants to the 2018 Workshop on Experimental Economics for the Environment in Hamburg, the AERNA 2018 Conference in Madrid and the 2019 Workshop on Behavioural and Experimental Methods in Manchester. Seminar participants at the Universities of Columbia and Innsbruck also provided helpful comments. Financial support was provided by the Austrian Science Fund (Grant Number P 25973-G11) and the Spanish Ministry of Economy and Competitiveness (projects ACBPA and TrenGood, ECO2012-35432 and ECO2017-84461-R).

References

Anderson, Simon P., Jacob K. Goeree, and Charles A. Holt. “Minimum-effort coordination games: stochastic potential and logit equilibrium.” *Games and Economic Behavior* 34 (2001): 177–199.

Bloch, Francis. “Endogenous structures of association in oligopolies.” *RAND Journal of Economics* 26 (1995): 537-556.

Bloch, Francis. “Non-cooperative models of coalition formation in games with spillovers.” In: Carraro, Carlo and Domenico Siniscalco (eds.), *New Directions in the Economic Theory of the Environment*. Cambridge University Press, Cambridge, ch. 10, pp. 311-352. (1997).

Brandts, Jordi and David J. Cooper. “Change would do you good ... An experimental study on how to overcome coordination failure in organizations.” *The American Economic Review* 96 (2006): 669-693.

Brandts, Jordi, David J. Cooper and Enrique Fatas. “Leadership and overcoming coordination failure with asymmetric costs.” *Experimental Economics* 10 (2007): 269–284.

Cachon, Gérard P. and Colin F. Camerer. “Loss-avoidance and forward induction in experimental coordination games.” *The Quarterly Journal of Economics* 111.1 (1996): 165-194.

Caparrós, Alejandro, and Michael Finus. “Public good agreements under the weakest-link technology.” *Journal of Public Economic Theory* (2020): 22(3): 555-582.

Chaudhuri, Ananish, Andrew Schotter and Barry Sopher. “Talking ourselves to efficiency: coordination in inter-generational minimum effort games with private, almost common and common knowledge of advice.” *The Economic Journal* 119 (2009): 91–122.

Cooper, Russell W., Douglas V. DeJong, Robert Forsythe and Thomas W. Ross. “Selection criteria in coordination games: some experimental results.” *The American Economic Review* 80.1 (1990): 218-233.

Croson, Rachel, Enrique Fatas, Tibor Neugebauer, Antonio J. Morales. “Excludability: a laboratory study on forced ranking in team production.” *Journal of Economic Behavior & Organization* 114 (2015): 13-26.

Devetag, Giovanna, and Andreas Ortmann. "When and why? A critical survey on coordination failure in the laboratory." *Experimental Economics* 10.3 (2007): 331-344.

Efron, B., “Bootstrapping methods: another look at the jackknife.” *Annals of Statistics* 7 (1979): 1-26.

Feri, Francesco, Bernd Irlenbusch, and Matthias Sutter. "Efficiency gains from team-based coordination-large-scale experimental evidence." *The American Economic Review* 100.4 (2010): 1892-1912.

Finus, Michael and Bianca Rundshagen. "Membership rules and stability of coalition structures in positive externality games." *Social Choice and Welfare* 32 (2009): 389-406.

Fischbacher, Urs. "z-Tree: Zurich toolbox for ready-made economic experiments." *Experimental Economics* 10.2 (2007): 171-178.

Greiner, Ben. "Subject pool recruitment procedures: organizing experiments with ORSEE." *Journal of the Economic Science Association* 1.1 (2015): 114-125.

Goeree, Jacob K. and Charles A. Holt. "An experimental study of costly coordination." *Games and Economic Behavior* 51 (2005): 349–364.

Goeree, Jacob K., Charles A. Holt and Thomas R. Palfrey. "*Quantal response equilibrium: a stochastic theory of games.*" Princeton University Press, Princeton (2016).

Haile, Philip A., Ali Hortaçsu and Grigory Kosenok. "On the empirical content of quantal response equilibrium." *The American Economic Review* 98 (2008): 180-200.

Hamman, John, Scott Rick and Roberto A. Weber. "Solving coordination failure with "all-or-none" group-level incentives." *Experimental Economics* 10 (2007): 285–303.

Hart, Sergiu and Mordecai Kurz. "Endogenous Formation of Coalitions." *Econometrica* 51 (1983): 1047-1064.

Lunneborg, Clifford E. "Jonckheere–Terpstra test." *Wiley StatsRef: Statistics Reference Online* (2005).

McKelvey, Richard and Thomas R. Palfrey. "Quantal response equilibrium for normal form games." *Games and Economic Behavior* 10 (1995): 6-38.

McKelvey, Richard and Thomas R. Palfrey. "Quantal response equilibria for extensive form games." *Experimental Economics* 1 (1998): 9–41.

Monderer, Dov and Lloyd S. Shapley. "Potential games." *Games and Economic Behavior* 14 (1996): 124–143.

Moulin, Herve. "*Axioms of cooperative decision making*." Econometric Society Monographs, Cambridge University Press (1991).

Moulin, Herve. "Serial Cost Sharing of Excludable Public Goods". *Review of Economic Studies* 55 (1994): 936–976.

Riedl, Arno, Ingrid M.T. Rohde, and Martin Strobel. "Efficient coordination in weakest-link games." *The Review of Economic Studies* 83.2 (2016): 737-767.

Rogers, Brian W., Thomas R. Palfrey and Colin F. Camerer. "Heterogeneous Quantal Response Equilibrium." *Journal of Economic Theory* 144 (2009): 1440-1467.

Salmon, Timothy C. and Roberto A. Weber. "Maintaining efficiency while integrating entrants from lower performing groups: an experimental study." *The Economic Journal* 127 (2017): 417–444.

Train, Kenneth E. "*Discrete choice methods with simulation: Second edition.*" Cambridge University Press, New York (2009).

Turocy, Theodore L. "Computing sequential equilibria using agent quantal response equilibria." *Economic Theory* 42 (2010): 255–269.

Van Huyck, John B., Raymond C. Battalio, and Richard O. Beil. "Tacit coordination games, strategic uncertainty, and coordination failure." *The American Economic Review* 80.1 (1990): 234-248.

Weber, Roberto A. "Managing Growth to Achieve Efficient Coordination in Large Groups." *The American Economic Review* 96. 1 (2006): 114-126.

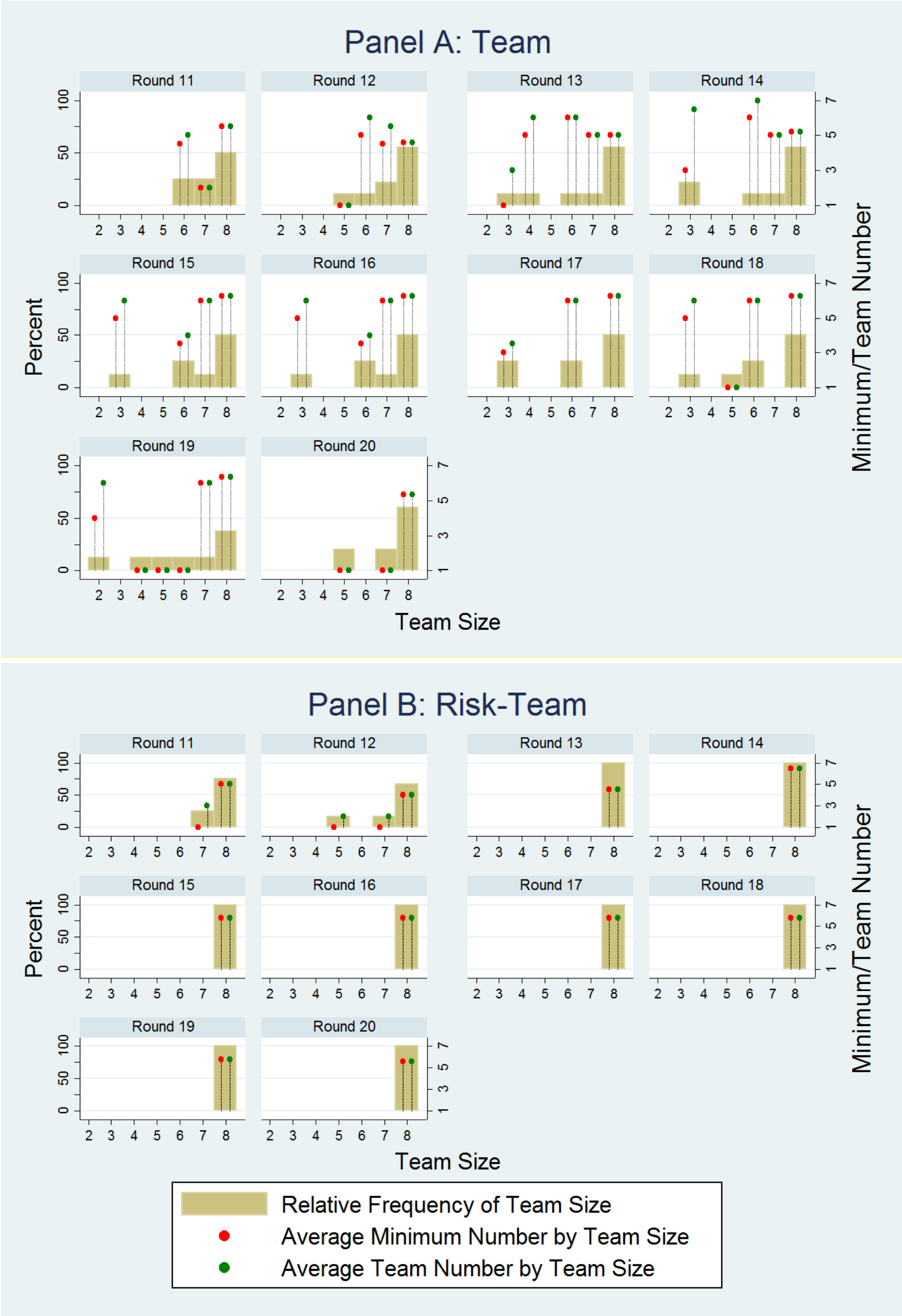
Yi, Sang-Seung. "Endogenous Formation of Economic Coalitions: A Survey of the Partition Function Approach." In: Carraro, Carlo (ed.), *The Endogenous Formation of Economic Coalitions*. Edward Elgar, Cheltenham, UK et al., ch. 3, pp. 80-127 (2003).

Supplementary Material for

“Team Formation in Coordination Games with Fixed Neighborhoods”

I. ADDITIONAL ANALYSES

Figure A1: Distribution of Sizes of Implemented Teams over Rounds



Note: The figure presents the distribution of different team sizes over rounds in treatments *Team* (Panel A) and *Risk-Team* (Panel B) together with the *minimum number* and the *average number* for each team size. The relative frequency of each team size in a round is calculated as the percentage of this team size relative to the total number of teams within this round. Relative frequencies sum up to 100 percent in each round. The minimum number for each team size is the arithmetic mean of minimum numbers over all groups with implemented teams of that size within the respective round. The average number for each team size is the arithmetic mean of team numbers over all groups with implemented teams of that size within the respective round.

Figure A2 - Development of Average Numbers separated by Groups in *Baseline*

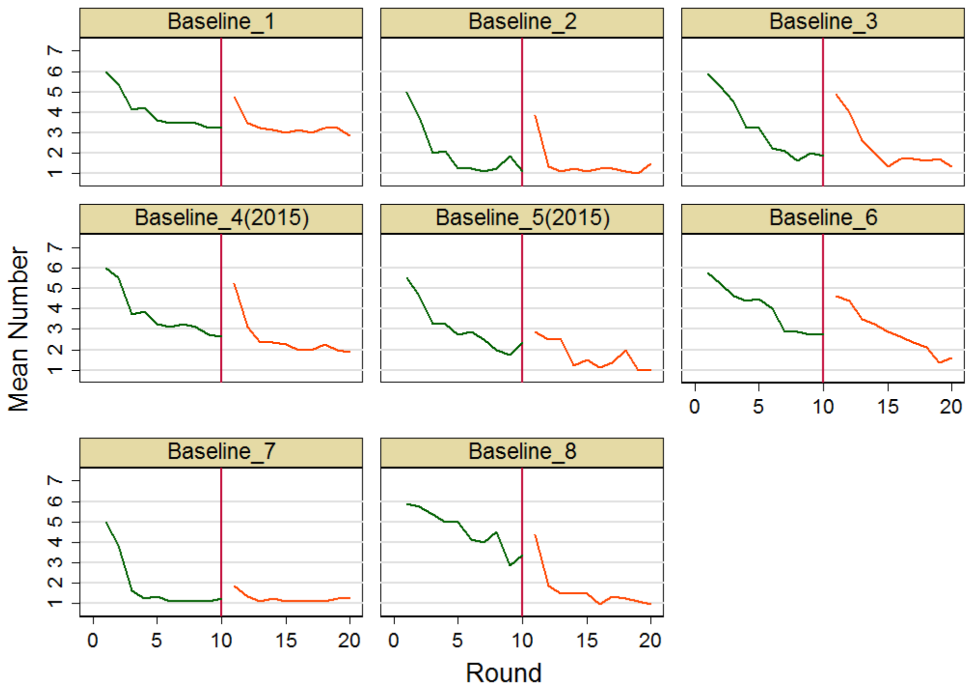


Figure A3 - Development of Average Numbers separated by Groups in *Team*

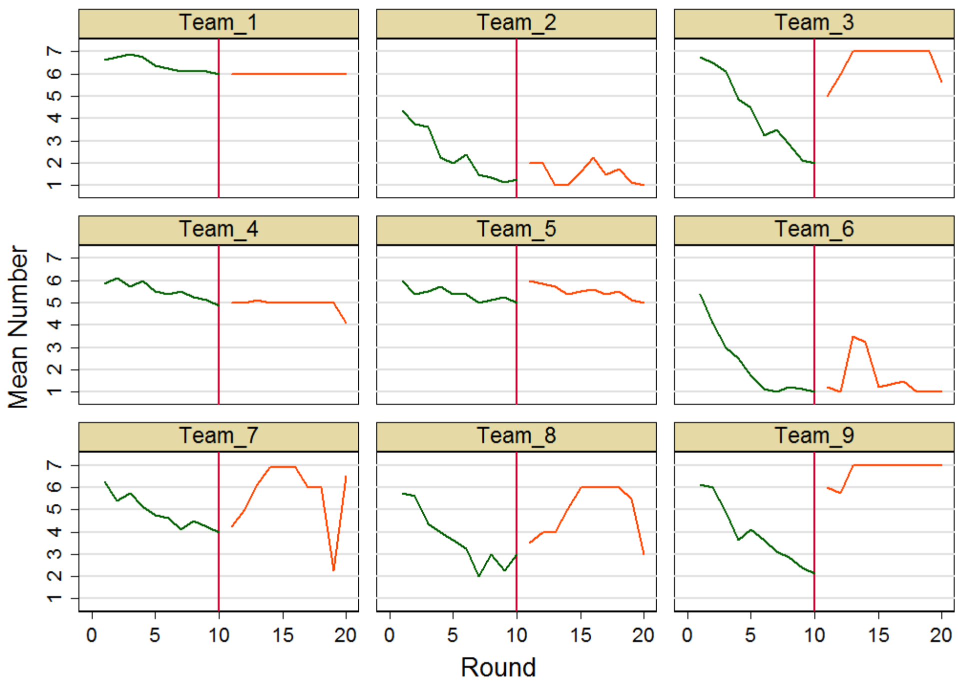


Figure A4 - Development of Average Numbers separated by Groups in *Risk*

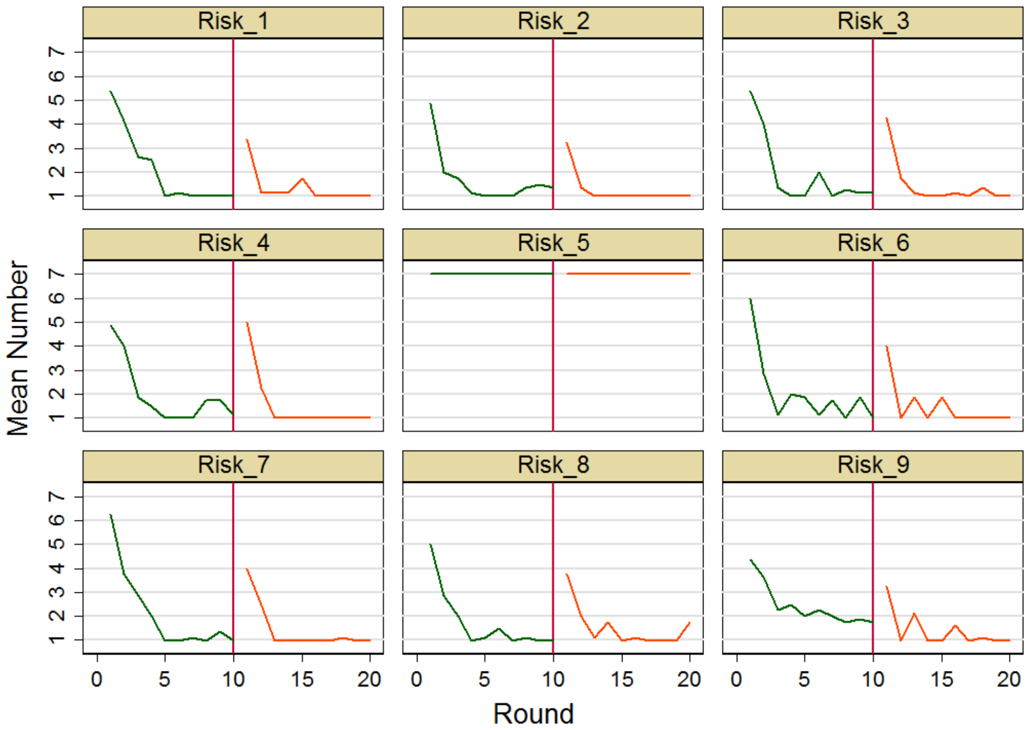


Figure A5 – Development of Average Numbers separated by Groups in *Risk-Team*

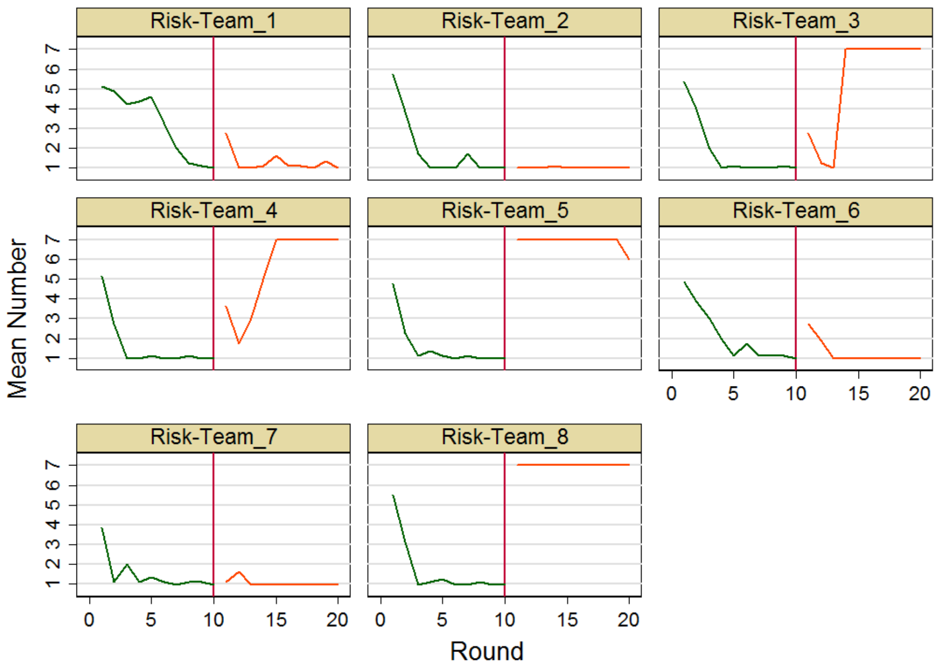


Figure A6 - Development of Minimum Numbers separated by Groups in *Baseline*

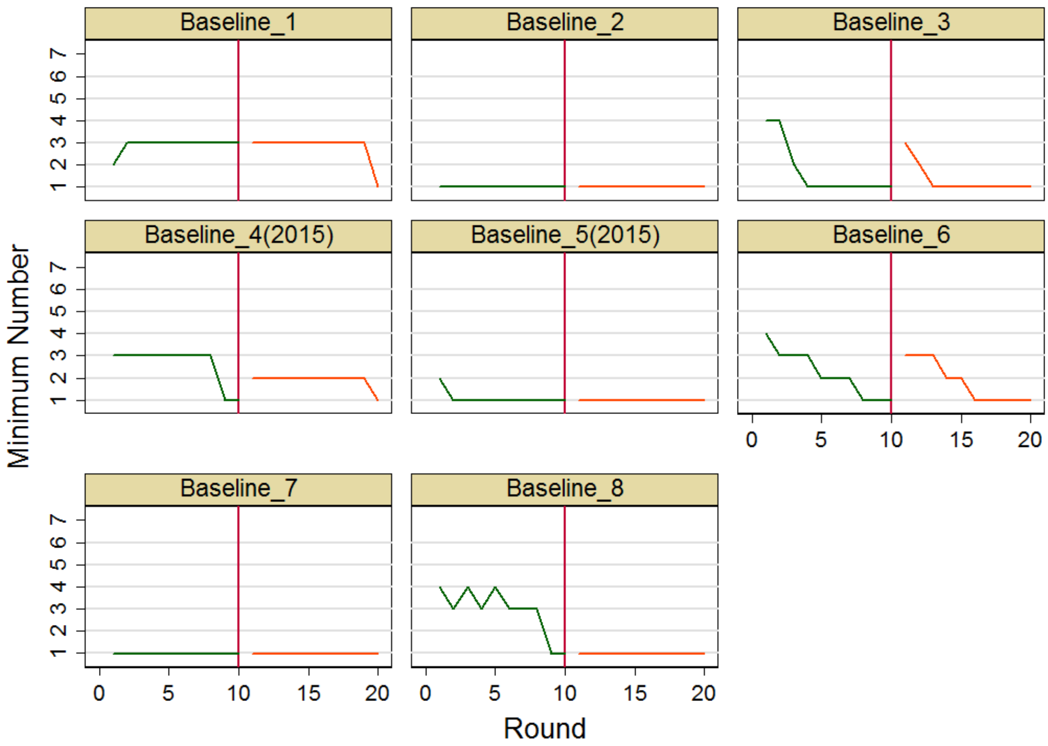


Figure A7 - Development of Minimum Numbers separated by Groups in *Team*

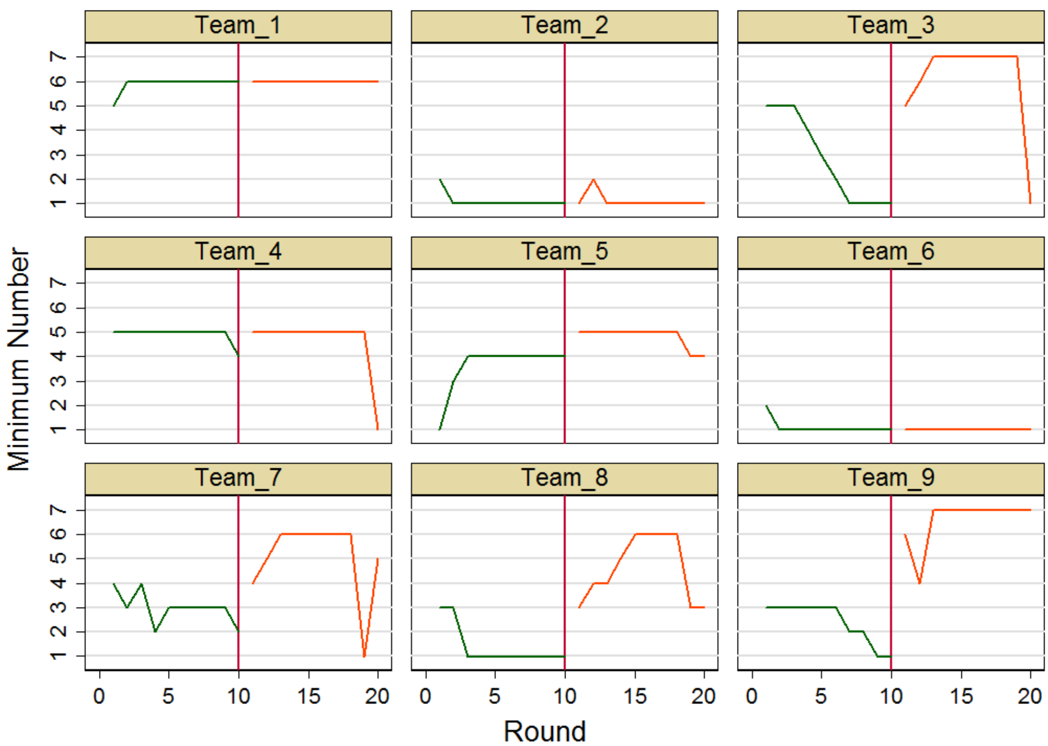


Figure A8 - Development of Minimum Numbers separated by Groups in *Risk*

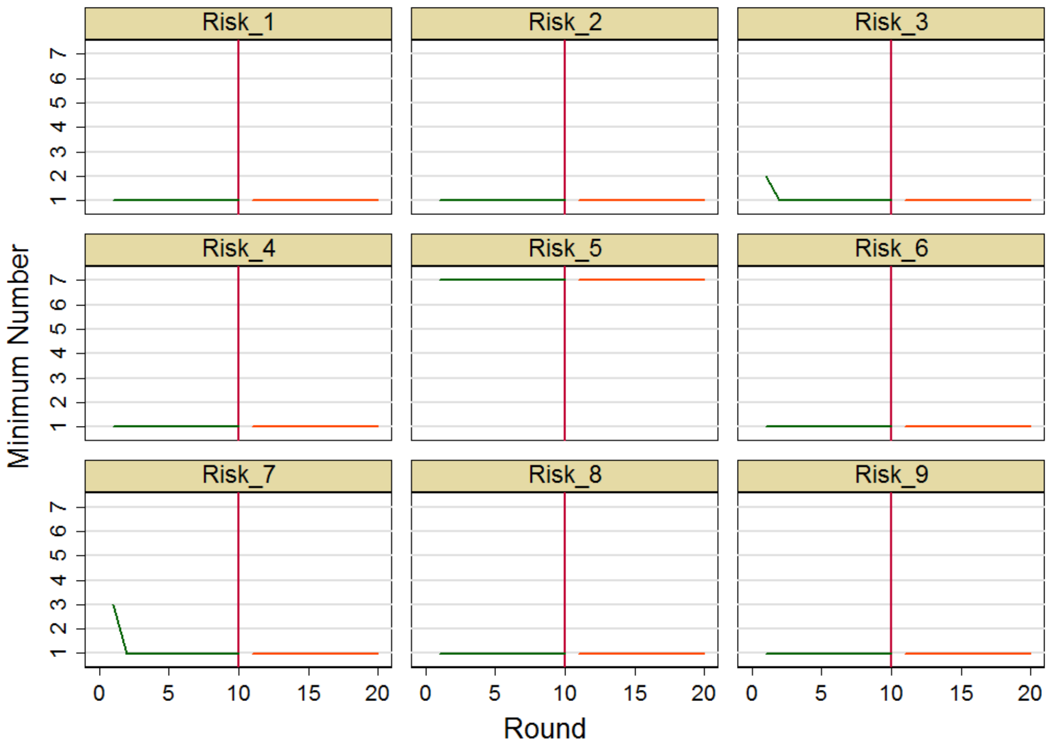


Figure A9 - Development of Minimum Numbers separated by Groups in *Risk-Team*

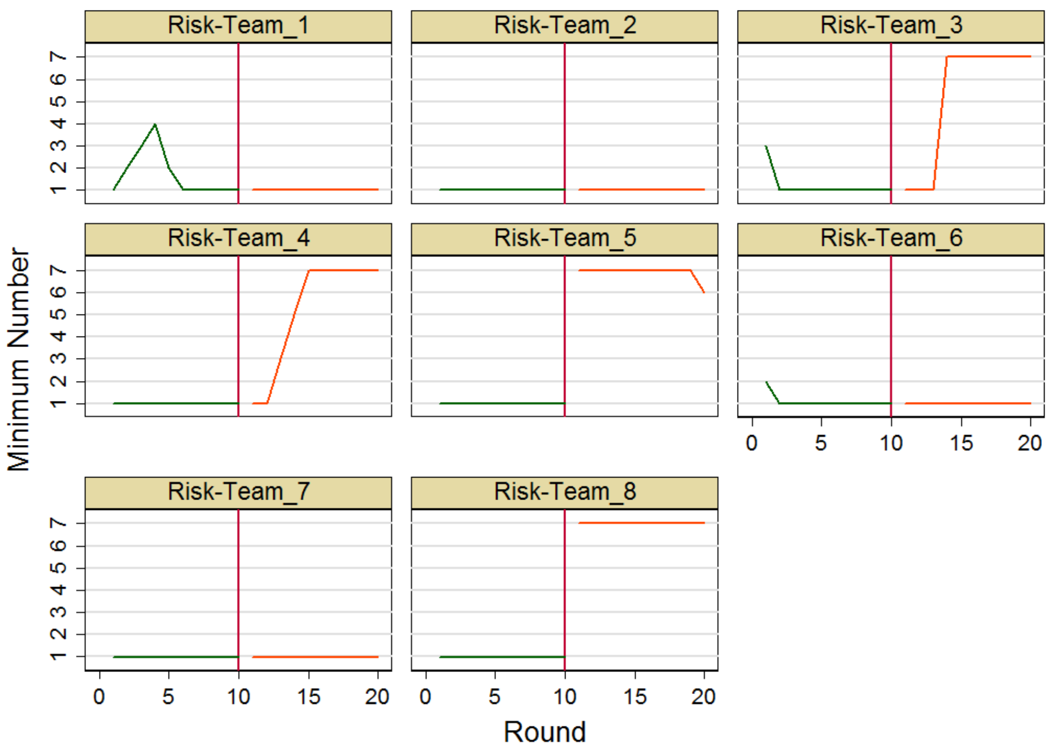


Table A.1: Average Numbers and Minimum Numbers in Part 1 and Part 2

Treatment	Average[(1)] Number in Part 1	Wilcoxon Signed-Rank Test[(3)]	Average Number in Part 2	Minimum[(2)] Number in Part 1	Wilcoxon Signed-Rank Test	Minimum Number in Part 2
Baseline	3.322	** (0.0117)	2.145	1.925	** (0.0192)	1.475
Team	4.289	(0.3743)	4.832	2.911	* (0.0750)	4.433
Risk	2.011	** (0.0116)	1.438	1.038	(0.1582)	1.000
Risk-Team	1.931	(0.2626)	3.688	1.125	(0.1780)	3.538

Notes: (1) Average Number: arithmetic mean of average numbers overall all rounds in part 2 over all groups with same treatment. (2) Minimum number: arithmetic mean of minimum numbers over all rounds in part 2 over all groups with the same treatment. (3) Significance of differences between parts, based on a Wilcoxon Signed-Rank Test. Significance at the 1 percent (***), 5 percent (**) and 10 percent (*) level. P-values are given in parentheses.

II. EXPERIMENTAL INSTRUCTIONS

The instructions were in German. Below, we present the English translation for Baseline and Team. The instructions for Risk and Risk-Team were equivalent to Parts 1 and 2 of Baseline and Team, with the exception that the payoff table was Table 2 instead of Table 1 (both in the manuscript). Moreover, the examples were adjusted accordingly.

Introduction: General instructions

WELCOME

This is an experiment on decision making. You start the session today with 4 euros and you will have the chance to earn money based on your decisions in this experiment. It is extremely important that you put away all materials including external reading material and turn off your cell phones and any other electronic devices.

If you have a question, please raise your hand and I will come by and answer your question. Talking is not permitted. Please read the instructions carefully, as your decisions and the decisions of others in the experiment will affect your final earnings.

Structure: Today's experiment comprises three parts, Part 1 to Part 3. The experiment will last approximately an hour and a half.

Cash Payment:

- Your earnings in this experiment are expressed in Points. At the end of the experiment you will be paid in Euros, using a conversion rate of 100 Points = 60 cents.
- Your earnings from the three parts are calculated independently for each part. Your total earnings from the experiment will be the sum of your payments in parts 1 to 3.

Your decisions and earnings will only be known to you and are not disclosed to others. The information you receive will be recorded by your participant number and **not** by your name.

The following instructions are for part 1. Prior to the start of the subsequent two parts, additional instructions will be given.

II.1 Part 1: Baseline and Team

You have been randomly assigned to a group of 8 people, you and 7 other participants. Neither during nor after the experiment will you be informed about the identities of the other members in your group.

Decision: In each round, each participant has to choose a **number** 1, 2, 3, 4, 5, 6 or 7.

Earnings in every round in Part 1: The number you choose and the smallest number chosen by all participants in your group (including your choice) will determine the payoff you receive in a round.

The earnings in each round may be found by looking at the table below, looking across from your number on the left-hand side of the table and down from the smallest number played by any participant in your group (including yourself) as listed at the top of the table.

Payoff Table

		Smallest number chosen by any participant in your group (including yourself)						
		7	**6**	**5**	**4**	**3**	**2**	**1**
Number you choose	**7**	130	110	90	70	50	30	10
	6		120	100	80	60	40	20
	5			110	90	70	50	30
	4				100	80	60	40
	3					90	70	50
	2						80	60
	1							70

Example:
If you choose number 4 and the smallest number chosen by other participants is 3, you earn 80 points in this round.

Final information screen: After all decisions have been taken in a round, you will see an "information window" with a summary of all decision in this round.

TOTAL earnings in Part 1: Your total earnings in Part 1 of the experiment will be the sum of all earnings in all 10 periods of Part 1.

Before making decisions, you will be asked to answer a set of short control questions designed to check your understanding.

CONTROL QUESTIONS

Consider one period:

1. If you choose number 7 and the smallest number in your group is 7
    a) your earnings are 130 points;
    b) your earnings are 10 points;
    c) different participants in your group earn different amounts.

(correct answer a)

2. If you choose number 7 and the smallest number in your group is 4
    a) your earnings are 100 points;
    b) you earn more than the participant(s) who chose number 4;
    c) your earnings are 70 points.

(correct answer c)

3. If you choose number 4 and the smallest number in your group is 4
    a) everyone in your group must earn the same;
    b) your earnings are 100 points;
    c) participants who choose higher numbers than 4 earn more than you.

(correct answer b)

4. If you choose number 1 and the smallest number in your group is 1
    a) your earnings are 10 points;
    b) it is not possible that other participants in your group chose higher numbers than 1;
    c) your earnings are 70 points.

(correct answer c)

II.2 Part 2: Baseline

Part 2 will consist of an additional *10 decision periods*. You remain in the *same group of 8 participants* as in Part 1. The decision situation and the calculation of your payoffs is exactly the same as in Part 1 of the Experiment.

As a reminder, we include below the payoff table again.

Payoff Table

	Smallest number chosen by any participant in your group (including yourself)						
Number you choose	**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	130	110	90	70	50	30	10
6		120	100	80	60	40	20
5			110	90	70	50	30
4				100	80	60	40
3					90	70	50
2						80	60
1							70

TOTAL earnings in Part 2: Your total earnings in Part 2 of the experiment will be the sum of all earnings in all 10 periods of Part 2.

II.3 Part 2: Team

Part 2 will consist of an additional *10 decision periods*. You remain in the *same group of 8 participants* as in Part 1.

As a reminder, we include below the payoff table again.

Payoff Table

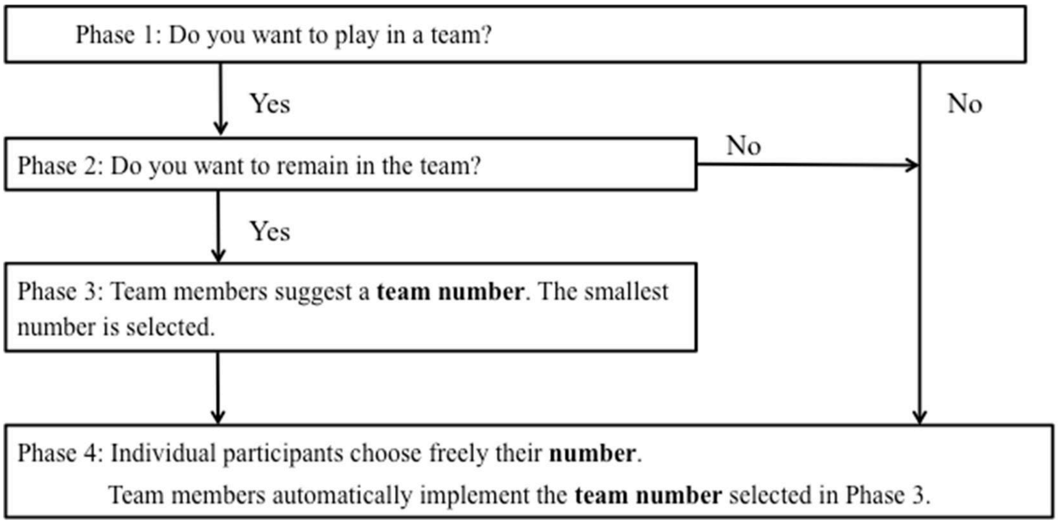
	Smallest number chosen by any participant in your group (including yourself)						
Number you choose	**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	130	110	90	70	50	30	10
6		120	100	80	60	40	20
5			110	90	70	50	30
4				100	80	60	40
3					90	70	50
2						80	60
1							70

In this part, there are 4 different phases in each round in which decisions have to be taken. The main difference with respect to Part 1 of the experiment is:

> A Team can form: all group members decide if they want to choose their **number** freely, that is as an *Individual Participant*, or jointly in a *Team* (phases 1 and 2).

Figure 1 presents a summary of the phases that we describe in detail below.

Figure 1



Detailed description of decisions:

Phase 1:

Decision: You need to decide if you want to play as an Individual or in a Team.

- If you decide to play as an Individual, your next decision is in phase 4.
- If you decide to play as a Team, and:
    - nobody else decides to join the Team, then everyone in your group moves to phase 4.
    - at least one other participant decides to join the Team, then Team Members move to phase 2.

Decision:

Play in a Team: Press 1 *Play as an Individual: Press 2*

Phase 2:

Initial Information: At the beginning of phase 2, all participants are informed about how many participants have decided to join the Team.

Decision: Each Team Member is asked to confirm if he/she wants to remain in the Team.

- If at least one Team Member does not confirm his/her Team membership, the Team is dissolved. Then, everyone in your group moves to phase 4.
- If all Team Members confirm their membership, Team Members move to phase 3.

Decision of Team Members:

Confirm membership: Press 1 *Reject membership: Press 2.*

Final Information: At the end of phase 2, all participants in your group are informed about whether the Team forms or the Team does not form.

Phase 3

Decision: Each Team Member suggests a number 1, 2, 3, 4, 5, 6, or 7 which must be implemented by every Team Member in phase 4. The smallest of these numbers will be used as the **team number** which will be implemented automatically by *all* Team Members.

Decision of Team Members: Suggest a team number

Enter Value: _____

Phase 4

Decision:

Team members: the **team number** agreed in phases 3 will be automatically implemented.

Individual participants: choose independently and freely a **number** 1, 2, 3, 4, 5, 6, or 7.

Decision of Individual Participants: Choose a number

Enter value:

Round earnings in Part 2: Your earnings in each round depend on the **number** you choose (as an Individual or as a Team), and the smallest **number** chosen by all participants in your group (including your choice). The payoff table describes earnings.

Final information screen: After all decisions have been taken in a round, you will see an "information window" with a summary of all decisions in this round.

TOTAL earnings in Part 2: Your total earnings in Part 2 of the experiment will be the sum of all earnings in all periods of Part 2.

Before making decisions, you will be asked to answer a set of short control questions designed to check your understanding.

CONTROL QUESTIONS

In a given period:

1. If you are a Team Member:
    a) in phase 4 you can choose freely the number you want to select;
    b) other Team Members can force you to a team number above the number you would like to choose;
    c) the team number you play in phase 4 is the smallest number proposed in your Team.

(correct answer c)

2) If you are an Individual Participant:
    a) in phase 4 you can choose freely the number you want to select;
    b) the decision of the Team does not affect your payoff;
    c) you can determine the team number.

(correct answer a)

3. If you are a member of a Team including 8 Team Members:
    a) the payoffs are determined by the team number;
    b) different participants in your group have different earnings;
    c) the payoffs you obtain depend on the choices of Individual Participants.

(correct answer a)

4. If you are member of a Team including 6 participants:
    a) different participants in your Team can obtain different payoffs;
    b) the payoffs of Team Members are affected by the decisions of individual participants.
    c) the Team includes all the participants in your group.

(correct answer b)

III. DETAILS ON THE (AGENT) QUANTAL RESPONSE EQUILIBRIUM

This Appendix describes in detail the QRE and the AQRE analyses presented in the main text. This allows us to write the Testable Predictions detailed in the main text. Before continuing, note that the VHBB payoff function, equation (1) in the main text, and the FIS payoff function, equation (2), can be written as depending on e_i and e^{min}, i.e. as $\Pi^V(e_i, e^{min})$ and $\Pi^F(e_i, e^{min})$. As the remainder of the Appendix applies to both payoff functions, we refer to a generic payoff function $\Pi(e_i, e^{min})$.

III.1 Correspondence without team formation (QRE)

As in the main text, σ_{ij} denotes the probability that player *i* selects the provision level (number) *j*. As we focus on symmetric equilibria all players are assumed to play according to the same σ, hence, we eliminate the subscript for the player to simplify notation. Thus, σ_j denotes the probability of selecting *j*. In addition, call β_{xy} the probability that if player *i* selects *x* the minimum is *y*. If player *i* plays 1, the probability that the minimum is 1, is equal to 1. Hence, $\beta_{11} = 1$. If player *i* plays 2, the probability that the minimum is 1 is the probability that any of the other player plays 1. To calculate this probability, we calculate the probability that no other player selects 1, and subtract it from 1. Thus, $\beta_{21} = 1 - (1 - \sigma_1)^{\mathrm{n}-1}$, where *n* is the total number of independent players. By the same token, we calculate:

$$\begin{aligned}
\beta_{32} &= (1 - (1 - \sigma_1 - \sigma_2)^{\mathrm{n}-1}) - \beta_{21},\\
\beta_{43} &= (1 - (1 - \sigma_1 - \sigma_2 - \sigma_3)^{\mathrm{n}-1}) - \beta_{32} - \beta_{21},\\
\beta_{54} &= (1 - (1 - \sigma_1 - \sigma_2 - \sigma_3 - \sigma_4)^{\mathrm{n}-1}) - \beta_{43} - \beta_{32} - \beta_{21},\\
\beta_{65} &= (1 - (1 - \sigma_1 - \sigma_2 - \sigma_3 - \sigma_4 - v_5)^{\mathrm{n}-1}) - \beta_{54} - \beta_{43} - \beta_{32} - \beta_{21},\\
\beta_{76} &= (1 - (1 - \sigma_1 - \sigma_2 - \sigma_3 - \sigma_4 - \sigma_5 - \sigma_6)^{\mathrm{n}-1})\\
&\qquad -\beta_{65} - \beta_{54} - \beta_{43} - \beta_{32} - \beta_{21}.
\end{aligned}$$

Using these probabilities, we calculate the expected payoffs of any number between 1 and 7. Dropping the index for the player, we call $V_j(\sigma)$ the expected payoff of selecting number *j*. These expected payoffs are calculated as follows:

$$\begin{aligned}
V_1(\sigma) &= \Pi(1,1),\\
V_2(\sigma) &= \beta_{21}\Pi(2,1) + (1 - \beta_{21})\Pi(2,2),\\
V_3(\sigma) &= \beta_{21}\Pi(3,1) + \beta_{32}\Pi(3,2) + (1 - \beta_{21} - \beta_{32})\Pi(3,3),
\end{aligned}$$

$$V_4(\sigma) \;=\; \beta_{21}\Pi(4,1) + \beta_{32}\Pi(4,2) + \beta_{43}\Pi(4,3) + (1 - \beta_{21} - \beta_{32} - \beta_{43})\Pi(4,4),$$

$$V_5(\sigma) = \beta_{21}\Pi(5,1) + \beta_{32}\Pi(5,2) + \beta_{43}\Pi(5,3) + \beta_{54}\Pi(5,4)$$
$$+(1 - \beta_{21} - \beta_{32} - \beta_{43} - \beta_{54})\Pi(5,5),$$

$$V_6(\sigma) = \beta_{21}\Pi(6,1) + \beta_{32}\Pi(6,2) + \beta_{43}\Pi(6,3) + \beta_{54}\Pi(6,4)$$
$$+(1 - \beta_{21} - \beta_{32} - \beta_{43} - \beta_{54} - \beta_{65})\Pi(6,6),$$

$$V_7(\sigma) = \beta_{21}\Pi(7,1) + \beta_{32}\Pi(7,2) + \beta_{43}\Pi(7,3) + \beta_{54}\Pi(7,4) + \beta_{65}\Pi(7,5)$$
$$+\beta_{76}\Pi(7,6) + (1 - \beta_{21} - \beta_{32} - \beta_{43} - \beta_{54} - \beta_{65} - \beta_{76})\Pi(7,7).$$

The next step is to estimate the system of equations defined in equation (3) in the main text. As we know that $\sum_{k=1}^{7} \sigma_j = 1$, we use the equation for σ_1 as a reference and divide it by all the other equations (following Turocy 2010). This yields the following system of equations:

$$\frac{\sigma_1}{\sigma_j} = \frac{\frac{e^{\lambda V_1(\sigma)}}{\sum_{k=1}^{7} e^{\lambda V_k(\sigma)}}}{\frac{e^{\lambda V_j(\sigma)}}{\sum_{k=1}^{7} e^{\lambda V_k(\sigma)}}} = e^{\lambda(V_1(\sigma) - V_j(\sigma))} \qquad \forall\, j = 2..7 \qquad \text{(A1)}$$

$$\sum_{k=1}^{7} \sigma_j = 1.$$

Taking the logarithm in the first six equations in (A1) we have:

$$\ln \sigma_1 - \ln \sigma_j = \lambda(V_1(\sigma) - V_j(\sigma)) \quad \forall\, j = 2..7.$$

We now conduct the following change of variables to facilitate the calculation: $\sigma_j = e^{a_j}$. Hence, we finally solve the following system of equations:

$$a_1 - a_j \;=\; \lambda(V_1(a) - V_j(a)) \quad \forall\, j = 2..7$$

$$\sum_{k=1}^{7} e^{a_j} = 1.$$

To solve this system of equations, we start by observing that for $\lambda = 0$ we obtain $\sigma_j = e^{a_j} = 1/7$ for all *j*. Using this as a starting point, we trace the solution for progressively larger values of λ, using always the equilibrium value of the previous value of λ as a starting point. This allows us to estimate the correspondence $\sigma^*(\lambda)$ for any value of λ. Calculating this for n=8 yields the logit correspondence for the case without team formation. There is a unique branch that connects the centroid to the Nash equilibrium where players play 1 with a probability tending to 1 when $\lambda \to \infty$. Using the logit correspondence, one can calculate the provision level (minimum number) and the averages numbers corresponding to the logit equilibrium for each value of λ. This yields an equilibrium provision level below 1.37 for every λ. The reason for this is that when players play randomly (λ=0), the probability that one of them plays a small number is already high enough to bring the expected minimum number down to 1.37. As λ

increases, the probability of playing low numbers increases and, hence, equilibrium provision levels decrease and converge to 1 when λ tends to ∞. Average numbers start at 4 for λ=0, decrease monotonically and converge to 1. This allows us to write our Testable Prediction (i).

III.2 Correspondence with team formation (AQRE)

For the case with team formation, we add an additional sub-script to denote the stage. As we solve the problem basically by backward induction, the second stage is identical to the problem without team formation just described. The only difference is that V_j is now written V_{j2} and what was σ_j is now σ_{j2}. An additional difference is that we solve the system of equations (A1) for all values of *n* between 1 and 8, as it depends on the number of independent players (i.e., there is 1 independent player if the grand team forms and 8 if no team forms). Hence, we use the notation $\sigma_{j2}^*(\lambda, n)$ to denote the correspondence for the second stage. This allows us to calculate the continuation values needed to solve the first stage.

Let $M(\lambda, n)$ denote the expected payoff associated with a team structure with *n* independent players:

$$M(\lambda, n) = \sum_{k=1}^{7} \sigma_{j2}^*(\lambda, n)\, V_{j2}(\sigma^*), \qquad \text{for } n = 1..8.$$

We further denote σ_{11} the probability of joining the team in the first stage. To calculate the expected payoff from joining the team, we first calculate the probability that the remaining *n*-1 players form a team of *s* players, for *s*=1, ..., *n*-1. This probability, denoted by Pr(s,σ_{11}), is given by the following expression:

$$\Pr(s, \sigma_{11}) = \sigma_{11}(1 - \sigma_{11})^{(n-1)-s} \binom{n-1}{s}.$$

Using this information, we calculate the expected payoff from joining the team as follows:

$$V_{11}(\sigma, \lambda) = \Pr(7, \sigma_{11}) M(\lambda, 1) + \Pr(6, \sigma_{11}) M(\lambda, 2) + \ldots + \Pr(0, \sigma_{11}) M(\lambda, 8).$$

If a player does not join the team, the expected payoff is (note that now the grand team is not possible, and that the all singleton structure results when no other player joins the team but also when only one player joins the team):

$$V_{21}(\sigma, \lambda) = \Pr(7, \sigma_{11}) M(\lambda, 2) + \Pr(6, \sigma_{11}) M(\lambda, 3) + \cdots$$
$$+ (\Pr(1, \sigma_{11}) + \Pr(0, \sigma_{11})) M(\lambda, 8).$$

We then solve the following equation numerically

$$\sigma_{11}(\lambda) = \frac{e^{\lambda V_{11}(\sigma,\lambda)}}{e^{\lambda V_{11}(\sigma,\lambda)} + e^{\lambda V_{21}(\sigma,\lambda)}},$$

to obtain $\sigma_{11}^*(\lambda)$.

With the VHBB and the FIS payoffs, the logit equilibrium when $\lambda \to \infty$ is that all players join the team with probability close to 1, and the grand team selects the provision level 7. However, there is no unique branch that connects the centroid to exactly one Nash equilibrium. With the VHBB payoff, there are three equilibria for $0.0838 \leq \lambda \leq 0.1004$ and a unique equilibrium elsewhere. With the FIS payoff, there are three equilibria for $0.0786 \leq \lambda \leq 0.2478$ and a unique equilibrium elsewhere. For all these equilibria the probability of joining the team is larger than 0.50 with both payoffs for any $\lambda > 0$ and equal to 0.50 for $\lambda = 0$. When intermediate teams are formed in equilibrium, minimum numbers are below 7. These results allow to write our Testable Prediction (ii).

Comparing the minimum numbers obtained with both logit correspondences yields our Testable Prediction (iii).

III.3 Log-likelihood functions

For the case without team formation, we estimate the following log-likelihood function:

$$\log L(\lambda, f) = \sum_{i=1}^{N} \sum_{j=1}^{7} f_{ij} \log(\sigma^*(\lambda)),$$

where the observed empirical frequencies of strategy choices are denoted by f, and f_{ij} represents the number of observations of player *i* choosing number *j*.

For the case with team formation, the log-likelihood function reads

$$\log L(\lambda, f) = \sum_{i=1}^{N} \left(\sum_{j=1}^{7} f_{ij2} \log(\sigma_{ij2}^*(\lambda)) + \sum_{j=1}^{2} f_{ij1} \log(\sigma_{ij1}^*(\lambda)) \right),$$

where f_{ij2} represents the number of observations of player *i* choosing number *j* at stage 2 and f_{ij1} the number of observations of player *i* choosing alternative *j* at stage 1. As there is no path that is continuously differentiable from 0 to ∞, as discussed in the previous sub-section, we use for each λ the equilibrium that is closer to the behavior observed in the data (see Goeree et al. 2016).

With and without team formation, we find the λ that maximizes the log-likelihood function numerically. Confidence intervals are estimated using the bootstrapping method (Efron, 1979; Train, 2009). This implies to create a large number of random samples, with repetition, from the original sample and to repeat the maximization process on all these samples. The standard error, δ, is then calculated as follows:

$$\delta = \sqrt{\frac{1}{R}\left(\hat{\lambda} - \lambda_R\right)^2},$$

where R=500 is the number of repetitions, λ_R the parameter estimated for the sample generated in each repetition, and $\hat{\lambda}$ the parameter estimated for the original sample.