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Efficiency Gains from Team-Based Coordination – Large-Scale Experimental Evidence*

By **Francesco Feri, Bernd Irlenbusch, and Matthias Sutter**

Abstract

The need for efficient coordination is ubiquitous in organizations and industries. The literature on the determinants of efficient coordination has focused on individual decision making so far. In reality, however, teams often have to coordinate with other teams. We present a series of coordination experiments with a total of 1,101 participants. We find that teams of three subjects each coordinate much more efficiently than individuals. This finding adds one important cornerstone to the recent literature on the conditions for successful coordination. We explain the differences between individuals and teams using the experience weighted attraction learning model. (JEL C71, C91, C92)

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Coordination problems prevail in a large variety of contexts, such as organizational design, technology adoption and diffusion, monopolistic competition, speculative attacks on currency markets, or bank runs, to name just a few (see, e.g., Thomas C. Schelling, 1980, James W. Friedman, 1994, Colin F. Camerer and Marc J. Knez, 1997, or Russell Cooper, 1999, for more examples). Due to the ubiquity of coordination problems and the eminent importance of successful coordination for the functioning of firms, organizations, or industries, there is a large body of research in economics on coordination games with multiple, often Pareto-ranked, pure strategy equilibria.[1] The equilibrium selection problems in these games resemble informal, decentralized coordination in situations which are hard to govern by explicit contracts. Since the determinants for coordination failure or success can more easily be controlled for and identified in laboratory studies than in field studies, most of the work on coordination has relied on controlled experiments, starting with the seminal papers by John B. Van Huyck, Richard C. Battalio and Richard O. Beil (1990, 1991) and Cooper et al. (1990, 1992). Strikingly, though, when examining the determinants of coordination failure or success, all experimental studies have exclusively focused on individual decision making so far.

In reality, however, teams often have to coordinate with other teams. In their classic book *The Wisdom of Teams*, Jon R. Katzenbach and Douglas K. Smith (1993) emphasize that the "team is the basic unit of performance for most organizations" (p. 27). Knez and Duncan Simester (2001) present an illuminating field study of the importance of team decision making in coordination games. They have studied the influence of incentive systems on the success of coordination at Continental Airlines. In particular, this airline offered a firm-wide bonus to all employees if specific on-time arrival and departure performance goals were met. This required the efficient coordination of several work teams on the ground (at the starting and landing airport) and in the air. Hence, Knez and Simester's (2001) case study serves as a prime example for coordination among teams. They were not interested in whether coordination among teams was more or less successful than coordination among individuals, though. In fact, except for a paper by Gary Charness and Matthew O. Jackson (2007) on an experimental Stag Hunt-game (which is a two-player coordination game), the literature has not yet addressed the comparative performance of individuals and teams in coordination games.[2] Even though their experiment is framed as bargaining in networks, in Charness and Jackson (2007) two persons form one team (i.e., one player). There is no interaction within a team other than each member deciding individually for one of the two strategies (Stag or Hare). If it is sufficient that one team member chooses the more efficient strategy (Stag) to implement it as the team decision, then team play was more efficient than in a control condition with individual play. This is mainly driven by the perception that if it only takes one vote out of two to implement Stag, it is much more likely that the other

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1 Coordination games have not only captured so much interest because they resemble many relevant real-world situations, but also because they are interesting from a genuine game-theoretical perspective, as they address the non-trivial issue of equilibrium selection (John Harsanyi and Reinhard Selten, 1988).

2 A very recent paper by Charness and Jackson (2009) studies individual decisions when one person is responsible for another person. They do not allow for any communication or interaction between the two persons, though, which is different from team decision making studied in Charness and Jackson (2007) and here.

pair will play Stag as well, so that choosing Stag carries less risk. If both team members have to choose Stag to implement it as the team decision, individual play is more efficient.

In this paper, we present a large-scale experimental study in order to examine whether individual or team decision making has any influence on coordination failure or success. In a first set of experiments with a total of 825 participants we extend the approach of Charness and Jackson (2007) in the following ways: (i) We set up teams of three members each. Team members can communicate with each other before making a decision, as this opportunity seems to characterize team decision making in many contexts. (ii) We let five – instead of only two – parties interact with each other. Since an increase in the number of interacting parties has been found to make efficient coordination more difficult, it seems warranted to examine coordination behavior of individuals and teams under such more demanding conditions. (iii) We study six different coordination games – two weakest-link games and four average-opinion games – and keep the procedure of decision making in the team constant. Our results show that teams are persistently and remarkably better at coordinating on efficient outcomes than individuals are. This holds true also in a second series of robustness check experiments with another 276 participants, where we examine in particular the influence of alternative procedures of decision making in teams. Only in a very simple 2x2-game we do not find significant differences between individuals and teams, indicating that only under the least demanding conditions individual decision making is no less efficient than team decision making. We explain the different behavior of individuals and teams by applying the experience weighted attraction learning model of Camerer and Teck-Hua Ho (1999). Teams are found in all games to be more attracted by payoff-dominant choices, which implies a higher probability of playing more profitable (i.e., more efficient) strategies.

The seminal contributions on experimental coordination games (Van Huyck et al., 1990, 1991; Cooper et al., 1990, 1992) left many researchers with the impression that coordination failure is a common phenomenon (Camerer, 2003). Coordination failure is understood as a group of subjects either failing to coordinate on one of the multiple (Pareto-ranked) equilibria of a coordination game (denoted as "miscoordination" in the following) or coordinating on a Pareto-dominated, i.e., inefficient, equilibrium due to subjects' strategic uncertainty about the other subjects' choices.[3]

Subsequent research has identified many factors that facilitate efficient coordination in firms and organizations.[4] Making the payoff-dominant equilibrium more attractive in relation to the risk-

[3] See Vincent P. Crawford (1991, 1995) for theoretical treatments of behavior in coordination games and how strategic uncertainty can affect the adaptive behavior of subjects in these games.

[4] Note that the excellent surveys on behavior in coordination games by Jack Ochs (1995) and Giovanna Devetag and Andreas Ortmann (2007) do not mention teams as a possible factor that influences the efficiency of play in coordination games. Besides those factors discussed in the text, the survey by Devetag and Ortmann (2007) discusses several other factors, like intergroup competition (Gary Bornstein, Uri Gneezy and Rosemarie Nagel, 2002), number of repetitions (Siegfried Berninghaus and Karl-Martin Ehrhart, 1998), feedback effects (Devetag, 2003, Jordi Brandts and David J. Cooper, 2006b), or matching effects (David Schmidt et al., 2003). Crawford, Gneezy and Yuval Rottenstreich (2008) show that salient labels may also promote more efficient coordination, but only as long as payoffs are symmetric. Even minutely asymmetric payoffs yield a very large degree of miscoordination in their two-person coordination games. Paola Manzini, Abdolkarim

dominant one – by scaling up financial incentives – has been shown to increase the efficiency of coordination (Jacob Goeree and Charles A. Holt, 2005; Brandts and Cooper, 2006a, 2006b; John Hamman, Scott Rick and Weber, 2007). The efficiency-increasing effect of pre-play cheap-talk communication has been strongly confirmed in two-person coordination games (Charness, 2000; John Duffy and Nick Feltovich, 2002, 2006). Andreas Blume and Ortmann (2007) have shown that costless cheap-talk through signaling one's intended action can yield efficient coordination even in large groups (of nine individuals). Concerning the influence of group size, Weber (2006, Table 2) shows that coordination gets less efficient with a larger group size. However, by slowly adding people (mainly one-by-one) to existing groups with a high level of efficiency it is possible to achieve efficient coordination also in large groups. Weber (2006) thus argues that achieving efficient coordination by managing growth may be one reason why firms and organizations that start out small may be successful in sustaining efficient coordination when they grow larger.

In this paper, we test a related hypothesis, i.e., that firms and organizations may be successful at sustaining efficient coordination by setting up teams that coordinate internally at first, but then coordinate across teams. Section I presents the coordination games that build the core of our paper. Section II introduces the experimental design. Section III reports the experimental results, and section IV uses the experience weighted attraction learning model to explain the differences between individuals and teams. Section V presents several robustness tests by adding new treatments. Section VI relates our findings briefly to the literature on team decision making. Section VII concludes the paper.

1. The Coordination Games

We have chosen two different types of coordination games for our study: weakest-link games and average-opinion games. Both types of games belong to the class of order-statistic games, with the minimum or the median of actions as the relevant order statistic.

A. The Weakest-Link Games in Detail

The first weakest-link game (denoted *WL-BASE* henceforth, see panel [A] of Table 1) is taken from Van Huyck et al. (1990). There are seven numbers to choose from. Payoffs increase in the minimum number chosen in the group, but decrease in the own number for a given minimum. Thus, the best response to a given strategy combination of the other players is to match the action of the "weakest link" with the lowest number. *WL-BASE* has seven pure-strategy, Pareto-ranked equilibria along the diagonal. Using the concept of payoff-dominance (Harsanyi and Selten, 1988) as an equilibrium selection device would lead to symmetric choices of "7" as the only equilibrium that is not strictly Pareto-dominated by any other equilibrium. Applying the maxi-

Sadrieh, and Nicolaas Vriend (2009) show that social conventions, like smiling, can make coordination more efficient.

min-criterion, though, would induce players to choose the lowest number, since choosing "1" guarantees the largest payoff in the worst possible case. Choosing such a "secure" action yields the least efficient equilibrium, however.

Table 1: Payoffs in the weakest-link games

[A] *WL-BASE*	Smallest number chosen in the group						
Own number	**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

[B] *WL-RISK*	Smallest number chosen in the group						
Own number	**7**	**6**	**5**	**4**	**3**	**2**	**1**
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

The second weakest-link game (denoted *WL-RISK*, see panel [B] of Table 1) has not been studied before. It keeps the property of Pareto-ranked equilibria, but reinforces the attraction of the maximin-criterion as a selection device since any number greater than "1" can lead to zero payoffs. Therefore, *WL-RISK* provides a stress-test of the relative importance of payoff-dominance versus taking a secure action.

B. The Average-Opinion Games in Detail

The first three average-opinion games shown in Table 2 are taken from Van Huyck et al. (1991), and the fourth one from Van Huyck et al. (1997). In game *AO-BASE* (panel [A]) the payoff-dominant equilibrium arises if all players choose "7", while the actions maximizing the minimum payoff are "3"s. Thus, *AO-BASE* entails a tension between payoff-dominance and taking a secure action. By setting all payoffs outside the diagonal to zero in *AO-PAY* (panel [B]), applying the maximin-criterion can no longer help in discriminating between the different equilibria. This leaves payoff-dominance as the most likely selection criterion. In *AO-RISK* (panel [C]), the equilibria along the diagonal are no longer Pareto-ranked. This means that payoff-dominance provides no guidance in this game, yet the maximin-criterion suggests choosing "4".

Table 2: Payoffs in the average-opinion games

[A] *AO-BASE*	Median number chosen in the group						
Own number	**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	130	115	90	55	10	-45	-110
6	125	120	105	80	45	0	-55
5	110	115	110	95	70	35	-10
4	85	100	105	100	85	60	25
3	50	75	90	95	90	75	50
2	5	40	65	80	85	80	65
1	-50	-5	30	55	70	75	70

[B] *AO-PAY*	Median number chosen in the group						
Own number	**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	130	0	0	0	0	0	0
6	0	120	0	0	0	0	0
5	0	0	110	0	0	0	0
4	0	0	0	100	0	0	0
3	0	0	0	0	90	0	0
2	0	0	0	0	0	80	0
1	0	0	0	0	0	0	70

Table 2 – continued

[C] *AO-RISK*	Median number chosen in the group						
Own number	**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	70	65	50	25	-10	-55	-110
6	65	70	65	50	25	-10	-55
5	50	65	70	65	50	25	-10
4	25	50	65	70	65	50	25
3	-10	25	50	65	70	65	50
2	-55	-10	25	50	65	70	65
1	-110	-55	-10	25	50	65	70

[D] *SEPARATRIX*	Median number chosen in the group													
Own number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	45	49	52	55	56	55	46	-59	-88	-105	-117	-127	-135	-142
2	48	53	58	62	65	66	61	-27	-52	-67	-77	-86	-92	-98
3	48	54	60	66	70	74	72	1	-20	-32	-41	-48	-53	-58
4	43	51	58	65	71	77	80	26	8	-2	-9	-14	-19	-22
5	35	44	52	60	69	77	83	46	32	25	19	15	12	10
6	23	33	42	52	62	72	82	62	53	47	43	41	39	38
7	7	18	28	40	51	64	78	75	69	66	64	63	62	62
8	-13	-1	11	23	37	51	69	83	81	80	80	80	81	82
9	-37	-24	-11	3	18	35	57	88	89	91	92	94	96	98
10	-65	-51	-37	-21	-4	15	40	89	94	98	101	104	107	110
11	-97	-82	-66	-49	-31	-9	20	85	94	100	105	110	114	119
12	-133	-117	-100	-82	-61	-37	-5	78	91	99	106	112	118	123
13	-173	-156	-137	-118	-96	-69	-33	67	83	94	103	110	117	123
14	-217	-198	-179	-158	-134	-105	-65	52	72	85	95	104	112	120

The game *SEPARATRIX* (see panel [D]) is also known as continental-divide game. It has a more complex choice set and two symmetric strict equilibria: {3, …, 3}, and {12, …, 12}.[5] The interesting facet of this coordination game is that adaptive behavior in the repeated game (assuming either myopic best response or fictitious play) will converge to the Pareto dominated equilibrium of {3, …, 3} when the first-round median is "7" or lower, but to the payoff-dominant equilibrium of {12, …, 12} when the first-round median is "8" or higher.

II. Experimental Design

We have set up two treatments for each of the six coordination games introduced above. In the "*Individuals*"-treatments we let five individuals interact in the respective game for 20 periods, and this partner matching is common information. In each period, each individual has to choose a number from the feasible set independently from the other individuals.

The "*Teams*"-treatments are, in principle, identical to the corresponding "*Individuals*"-treatments, except that a group of decision-makers consists of five teams – instead of five individuals. In the following we use the term "group" to denote the entity of players that interact with each other. The "group size" is always five in our experiment. The term "team" refers to three subjects who are requested to arrive at a joint team decision by agreeing on a single number to be chosen by all team members. We implement this unanimity rule to allow for the emergence of a true efficiency enhancing-effect of teams without potentially influencing the efficiency by an imposed voting procedure (compare the results by Charness and Jackson, 2007; for a treatment with a predetermined voting procedure see section V). Team members can communicate via an electronic chat (in which only revealing one's identity or using abusive language is forbidden). The experimental instructions (available in Supplement A) do not specify how team members should arrive at a team decision. Each team member has to enter the team's decision individually on his computer screen.[6] In the *Teams*-treatments the payoffs in the matrix are understood as a per-capita payoff for each team member. This approach is taken to keep the individual marginal incentives constant across the *Individuals*- and *Teams*-treatments.

The feedback given after each period is identical in the *Teams*- and *Individuals*-treatments. Each decision-maker is informed about the own payoff and the relevant order statistic, i.e., either the minimum or median number.

5 There is also an asymmetric equilibrium where three decision makers choose "14" and two pick "12" or "13". Van Huyck et al. (1997) never observed coordination on such an asymmetric equilibrium, though.

6 If different numbers were entered, team members could chat again and enter a decision once more. Only if the second attempt failed again the team received no payment in this period and the order statistic was computed by excluding this team. Note that this happened only in 3 out of 3,900 cases where teams had to reach an agreement.

Table 3: Experimental design

Coordination game	Number of participants *Individuals*	*Teams*	Number of groups/observations *Individuals*	*Teams*	Choices (sym. Equilibria) Payoff-dominant	Maximin
WL-BASE (Tab. 1 [A])	90	135	18	9	7	1
WL-RISK (Tab. 1 [B])	30	90	6	6	7	1
AO-BASE (Tab. 2 [A])	30	90	6	6	7	3
AO-PAY (Tab. 2 [B])	30	90	6	6	7	-
AO-RISK (Tab. 2 [C])	30	90	6	6	-	4
SEPARATRIX (Tab. 2 [D])	30	90	6	6	12	3

Note that "groups" refers to a unit of five decision makers, either five individuals or five teams. Teams always consist of three subjects who can communicate via an electronic chat.

Table 3 summarizes our experimental design. We used zTree (Urs Fischbacher, 2007) for programming and ORSEE (Ben Greiner, 2004) for recruiting participants. The weakest-link games were run at the University of Cologne, and the average-opinion games at the University of Innsbruck. No subject was allowed to participate in more than one session. The average duration was 45 minutes in *Individuals*-sessions, respectively 65 minutes in *Teams*-sessions. The exchange rate of points (indicated in Tables 1 and 2) into Euro was 200 points = 1€. The average performance-related earnings were 9€ per subject, plus a show-up fee of 2.5€.

III. Experimental Results

Table 4 presents an overview of the main data. In panel [A] it shows the average numbers chosen in the very first period. The first-period data are particularly interesting because these choices can not have been influenced by any history of the game. Therefore, the first-period data indicate "genuine" differences in coordination behavior between individuals and teams, irrespective of any differences due to learning.

Table 4: Main results

Coordination game	[A] Average numbers in 1st period: *Individuals*		*Teams*	[B] Average numbers overall: *Individuals*		*Teams*
WL-BASE (Tab. 1 [A])	5.98	**	6.53	4.56	*	6.09
WL-RISK (Tab. 1 [B])	5.37	***	6.37	1.97		3.70
AO-BASE (Tab. 2 [A])	5.67		6.17	6.57	**	6.94
AO-PAY (Tab. 2 [B])	5.33	***	6.43	6.04	**	6.95
AO-RISK (Tab. 2 [C])	4.43		4.40	4.07		4.03
SEPARATRIX (Tab. 2 [D])	7.90	***	11.03	9.80	**	12.63

	[C] Average Minima / Medians: *Individuals*		*Teams*	[D] Average payoffs: *Individuals*		*Teams*
WL-BASE (Tab. 1 [A])	3.91	**	5.79	92.6	**	114.9
WL-RISK (Tab. 1 [B])	1.30		3.42	53.1	***	85.0
AO-BASE (Tab. 2 [A])	6.63		6.97	124.8	**	129.3
AO-PAY (Tab. 2 [B])	5.99	**	6.98	103.3	**	127.1
AO-RISK (Tab. 2 [C])	4.00		4.00	68.5		69.6
SEPARATRIX (Tab. 2 [D])	9.85	**	12.77	93.2	***	114.2

***** (**) [*]** *significant difference between individuals and teams at the 1% (5%) [10%] level (Mann-Whitney U-test)*
All numbers chosen in the first period are used for testing (panel [A]), i.e., *all five* numbers from each single group. Note that all first-period choices are independent. When examining the average data across all 20 periods (panels [B]-[D]), we treat each group (with five decision-makers) as *one* independent unit of observation.

Both in the first period as well as across all 20 periods (see panel [B] of Table 4) the average numbers of teams are higher than those of individuals in all games with Pareto-ranked equilibria, and the differences are in most cases significant.[7] Only in game *AO-RISK* - in which equilibria are *not* Pareto-ranked – the average numbers are practically the same for individuals and teams. This pattern suggests that teams care more about payoff-dominance and less about the maximin-criterion than individuals do.

[7] Note that for testing we can use all first-period choices, i.e., we can take *all five* numbers from each single group, because first-period choices are independent. When examining the average data across all 20 periods, we treat each group (with five decision-makers) as *one* independent unit of observation. Table 3 shows the number of independent observations at the group-level. Except for *WL-BASE* it is always 6.

Figure 1: Average numbers in the weakest-link games

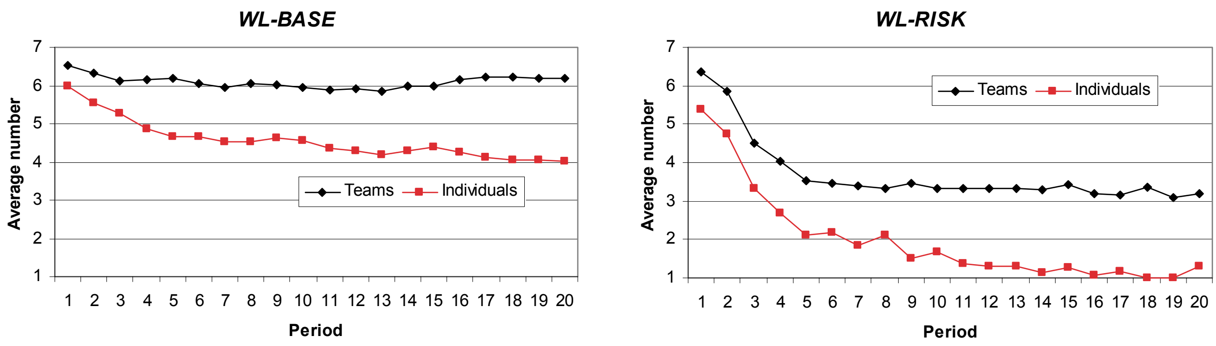


Figure 2: Average numbers in the average opinion games

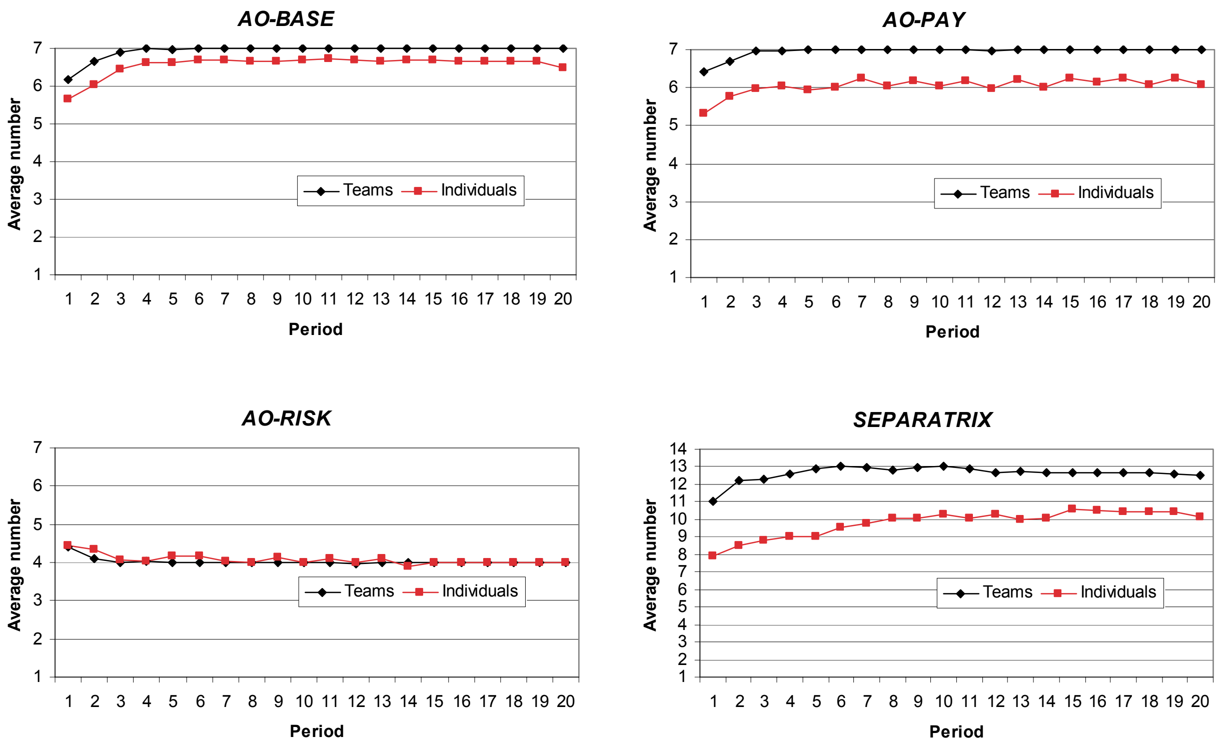


Figure 3: Relative frequencies of chosen numbers over all periods in weakest-link games

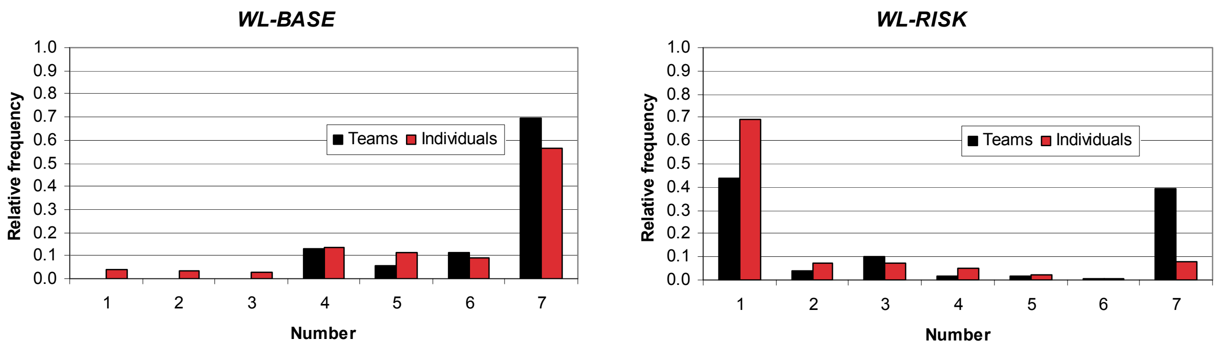
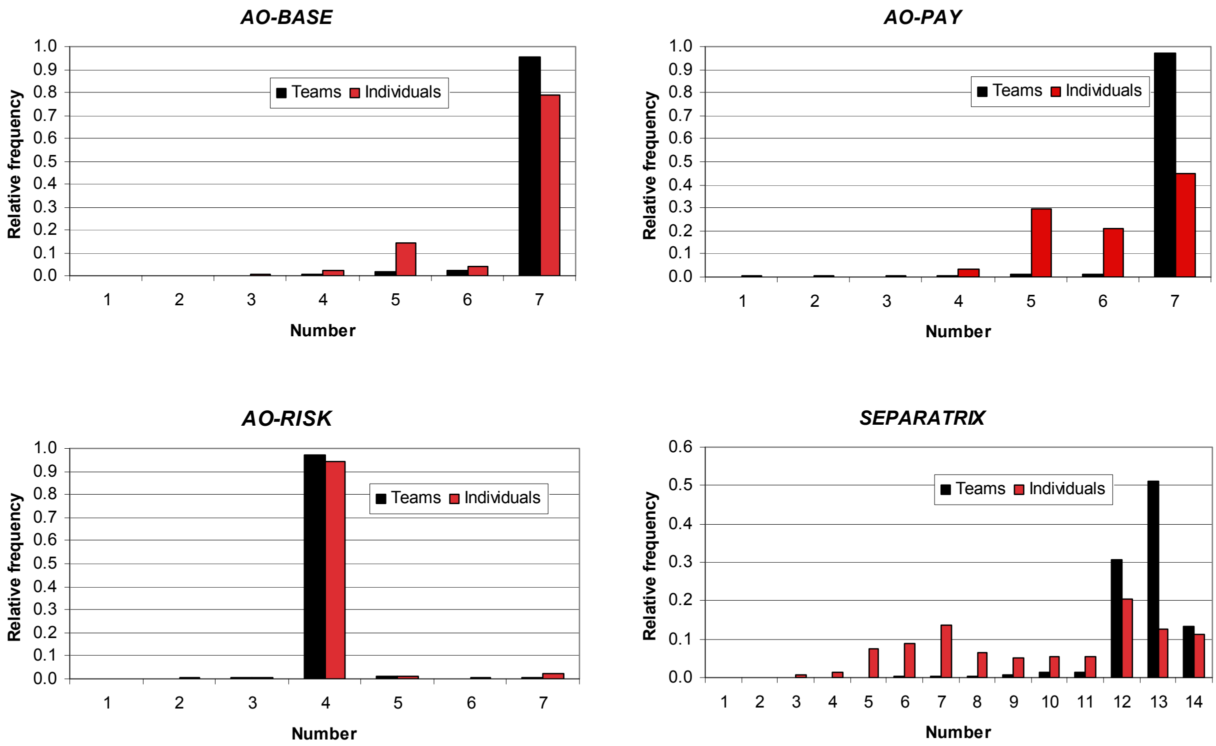


Figure 4: Relative frequencies of chosen numbers over all periods in average-opinion games



Figures 1 and 2 show the development of averages across periods. In the five games where payoff-dominance applies, teams choose higher numbers in every single period.[8] This statement is also clearly supported by Figures 3 and 4, which present the relative frequencies of choosing a particular number.[9] In each single game with payoff-dominance, the distribution of numbers is shifted to the right by team decision making.

Turning from the chosen numbers to the actually resulting minimum, respectively median, numbers within groups, we see from panel [C] of Table 4 that teams generally succeed in coordinating on higher minimum or median numbers. As a consequence, teams have substantially and significantly higher payoffs than individuals, as can be seen in panel [D] of Table 4. Across all six games, teams earn on average about 20% more per capita than individuals, and the difference is significant in all games where payoff-dominance applies. We summarize these findings in our first result:

Result 1. *Teams choose higher numbers, i.e., they target the more efficient equilibria rather than the more secure ones in all games with Pareto-ranked equilibria. This yields significantly higher profits for teams. Only when payoff-dominance does not discriminate between the different equilibria we find no differences between individuals and teams with respect to chosen numbers and profits.*

8 While in the weakest-link games choices of individuals and teams tend to go down over time, in three of the average opinion games the average of the chosen numbers goes up, in particular in the early periods. In the game *AO-RISK* the average numbers are virtually constant over time and identical for individuals and teams.

9 Supplement B shows the distribution of chosen numbers separately for each single group and period.

Table 5: Coordination and adjustment

Coordination game	[A] Miscoordination Indiv.		Teams	[B] Perfect coordination Indiv.		Teams	[C] Adjustment Indiv.		Teams
WL-BASE	0.65	**	0.30	0.41	*	0.69	0.60	*	0.29
WL-RISK	0.67	**	0.29	0.42	**	0.77	0.53	**	0.21
AO-BASE	0.14	***	0.06	0.75	**	0.89	0.09	**	0.03
AO-PAY	0.25	**	0.03	0.61	**	0.92	0.34	*	0.02
AO-RISK	0.12		0.04	0.75		0.91	0.10		0.01
SEPARATRIX	0.84	***	0.51	0.04		0.04	0.98	***	0.56

[A] Miscoordination is defined as the average of the absolute difference between a decision-maker's number and the minimum/median in the same period.
[B] Perfect coordination is defined as the fraction of periods where all five decision-makers choose the same number.
[C] Adjustment is defined as average of the absolute difference between a decision-maker's own number and the minimum/median in the previous period.
**** (**) [*] significant difference between individuals (Indiv.) and teams at the 1% (5%) [10%] level (Mann-Whitney U-test)*

The superiority of teams with respect to payoffs is also driven by a significantly smaller amount of miscoordination. Table 5 presents three different indicators for this statement. Miscoordination (panel [A]) is measured as the average absolute deviation of each of the five chosen numbers from the actual minimum/median in a given group and period. This indicator is always larger for individuals than for teams, and again significant for all games with payoff-dominance. Panel [B] reports the relative frequency over all periods in which perfect coordination is achieved by all five decision makers choosing the same (not necessarily the most efficient) number. Except for *SEPARATRIX* and *AO-RISK*, teams succeed in perfect coordination significantly more often than individuals. The third indicator "adjustment" (panel [C]) measures the absolute differences between a decision-maker's number in period t and the minimum/median in period $t-1$. Table 5 shows that there is always more "adjustment" going on in the *Individuals*-treatments, implying that teams settle quicker in an equilibrium. This yields our next result:

Result 2. *Teams are more successful at avoiding miscoordination and settle into an equilibrium more quickly.*

IV. Econometric Analysis Using the Experience Weighted Attraction Learning Model

In this section, we present an econometric analysis of learning in order to explain in more detail why teams are much more successful in coordinating efficiently than individuals. We use the experience weighted attraction (EWA) learning model of Camerer and Ho (1999). In the EWA-model players' strategies have attractions that reflect initial predispositions and are updated by taking into account past outcomes. In a nutshell, the EWA-model integrates reinforcement learning models and belief-based models (like fictitious play) into a single learning model. The following subsection offers a brief account of the EWA-model, which is then followed by a subsection presenting the estimation results and how learning differs between individuals and teams.

A. A Brief Account of EWA-Learning

We start with notation. For each player (either individual or team) there are *m* pure strategies (*m* = 14 in *SEPARATRIX*, *m* = 7 in all other games). Let s_i^j be player *i*'s strategy *j*, and $s_i(t)$ the strategy of player *i* in period *t*. At time *t* the relevant order statistic is denoted by $z(t)$. Player *i*'s payoff of choosing strategy s_i^j in time *t* is $\pi_i(s_i^j, z(t))$. For player *i* strategy *j* in period *t* has a numerical attraction $A_i^j(t)$, which determines the probability of choosing strategy *j* in period *t* + 1 by the following logistic function:

$$P_i^j(t+1) = \frac{e^{\lambda A_i^j(t)}}{\sum_{k=1}^{m} e^{\lambda A_i^k(t)}}. \tag{1}$$

The parameter λ represents the response sensitivity for mapping attractions into choice probabilities. If $\lambda = 0$, strategies would be chosen randomly, $\lambda = \infty$ would imply best response. The attractions for each strategy are updated after each period according to the following equation:

$$A_i^j(t) = \frac{\phi \cdot N(t-1) \cdot A_i^j(t-1) + \{\delta + [1-\delta] I(s_i^j, s_i(t))\} \pi_i(s_i^j, z(t))}{N(t)}, \tag{2}$$

where $N(t)$ is a weight on the past attractions following the updating rule $N(t) = \phi(1-\kappa)N(t-1)+1$. The indicator function $I(x,y)$ is equal to zero if $x \neq y$ and one if $x = y$. Variables $N(t)$ and $A_i^j(t)$ have initial values $N(0)$ and $A_i^j(0)$, respectively, reflecting pregame experience. The parameter δ determines the weight put on foregone payoffs in the updating process and places a positive weight on unchosen strategies only if $\delta > 0$. Parameter ϕ discounts previous attractions. A lower ϕ reflects a higher decay of previous attractions due to forgetting or deliberately ignoring old experience in case the environment changes. Parameter κ determines the discount rate of the experience weight $N(t)$.[10]

[10] Note that Camerer and Ho (1999) formulate this slightly differently, albeit equivalently, in their paper. They define $N(t) = \rho N(t-1)+1$. From the working-paper of Ho, Camerer and Juin-Kuan Chong (2001), it becomes clear that $\rho = \phi(1-\kappa)$, which we use here.

For estimating model parameters we use the method of maximum likelihood and, to ensure model identification, we impose the necessary restrictions on the parameters λ, ϕ, κ, δ and $N(0)$ [11]. Then, for each treatment and game, we estimate initial attractions as described in Ho, Xin Wang, and Camerer (2008).[12] The likelihood function to estimate is then given by:

$$L(\lambda, \phi, \delta, \kappa, N(0)) = \prod_{i=1}^{5} \left[\prod_{t=1}^{20} P_i^{s_i(t)}(t) \right], \tag{5}$$

B. EWA-Estimates for Individuals and Teams

Table 6: Parameter estimates of EWA learning model

Game	Parameter	Teams	Individuals	Game	Parameter	Teams	Individuals
WL-BASE	λ *	5.835	4.360	*WL-RISK*	λ ***	3.226	1.630
		(0.827)	(0.182)			(0.334)	(0.156)
	ϕ ***	0.582	0.722		ϕ ***	0.601	0.793
		(0.037)	(0.018)			(0.054)	(0.031)
	δ	0.728	0.702		δ	0.490	0.456
		(0.033)	(0.018)			(0.058)	(0.068)
	κ	0.724	0.686		κ	1.000	1.000
		(0.247)	(0.067)			(0.001)	(0.000)
	N(0)	1.191	1.293		*N(0)*	0.696	0.372
		(0.208)	(0.085)			(0.193)	(0.148)
AO-BASE	λ ***	14.283	7.869	*AO-PAY*	λ *	3.430	1.500
		(0.185)	(2.312)			(1.049)	(0.121)
	ϕ***	1.000	0.631		ϕ	0.714	0.857
		(0.004)	(0.064)			(0.089)	(0.028)
	δ ***	0.968	0.710		δ *	0.720	0.227
		(0.016)	(0.056)			(0.279)	(0.067)
	κ*	0.946	0.300		κ	0.434	0.694
		(0.224)	(0.297)			(0.283)	(0.108)
	N(0)	1.057	1.789		*N(0)*	1.678	1.350
		(0.250)	(0.648)			(0.621)	(0.289)
AO-RISK	λ ***	23.034	12.04	*SEPARA-TRIX*	λ ***	7.814	3.821
		(0.074)	(1.766)			(1.422)	(0.391)
	ϕ	0.812	0.894		ϕ	0.685	0.620
		(0.096)	(0.080)			(0.037)	(0.042)
	δ ***	0.978	0.137		δ ***	0.868	0.717
		(0.035)	(0.120)			(0.017)	(0.025)
	κ ***	0.993	0.000		κ	0.810	1.000
		(0.067)	(0.001)			(0.224)	(0.001)
	*N(0)**	0.851	3.993		*N(0)***	0.198	0.876
		(0.324)	(1.715)			(0.204)	(0.211)

**** (**) [*] significant difference between teams and individuals at the 1% (5%) [10%] level.*

Figures in brackets indicate standard errors.

11 $\lambda \in [0, \infty]$, $\phi, \delta, \kappa \in [0,1]$ and $N(0) \in \left[0, \frac{1}{1-(1-\kappa)\phi}\right]$

12 The method proposed in Ho et al. (2008) is better suitable to approximate actual first-period data by the estimated initial attractions than the method initially described in Camerer and Ho (1999). For the same game and treatment we assume that initial attractions are equal for all players.

In Table 6 we report the estimates for parameters λ, ϕ, δ, κ and $N(0)$ in the EWA learning model.[13] The most important result is that in each single game, teams have a larger λ than individuals, and this difference is statistically significant in all games.[14] This means that the sensitivity of teams to attractions is always larger. Hence, if teams and individuals faced equal attractions, teams would be more likely to choose the strategy with the highest attraction.

In all *AO*-games, we observe a significantly larger δ for teams. This means that in the process of updating stragegies' attractions, teams take into account the hypothetical payoffs from unchosen strategies much more than individuals do. In other words, teams are more of the fictitious-play learning-type, whereas individuals are closer to a pure reinforcement learning-type. This difference between individuals and teams affects, of course, the dynamics of play since strategies with higher payoffs (even if not chosen) accumulate higher attractions, which are then chosen more likely by teams. As a consequence, team decisions are more heavily centered on higher numbers in games with Pareto-ranked equilibria. This yields a larger degree of efficient coordination and ultimately higher payoffs for teams than individuals.

Overall, the estimations for λ and δ reveal the most striking differences in learning between individuals and teams. The probability to play a strategy corresponding to the previous minimum, or median, is increasing in the parameters λ and δ, meaning that higher λ and δ make it more likely that in period t decision-makers choose the order statistic of period t–1. This yields less miscoordination and quicker settlement in equilibrium in the *Teams*-treatments. We summarize the insights from the EWA-learning model as follows:

Result 3. According to the experience weighted attraction learning model, teams have a higher sensitivity to the different strategies' attractions in all games. Moreover, in the attraction updating process teams pay more attention to the payoffs of unchosen strategies in the AO-games, while they discount old attractions more heavily in the WL-games. These facts imply a higher probability of playing more profitable strategies, leading ultimately to more efficient coordination when equilibria are Pareto-ranked.

V. Robustness Checks: Decision Making Procedure in Teams and the Number of Players

In this section we present two sets of robustness checks. In the first subsection we check whether the results reported so far are robust to the procedure of decision making in a team. In the second subsection we reduce the number of players and available strategies.

13 The parameters are determined by a single estimation using all data of one treatment rather than computing the averages of parameters for each single group as defined in (5).

14 Note that aggregate data for *AO-RISK* (in Figure 2) look very similar for individuals and teams, but the estimations show a significant difference in λ between individuals and teams. The larger λ for teams is due to teams deviating less (and less often) from previous medians than individuals.

A. Two Different Team Decision Making Formats in WL-BASE

We use the *WL-BASE* game (see Table 1 [A]) as the basis for checking the influence of different team decision making formats. Motivated by the suggestions of a referee, we implement two different procedures. The first procedure uses a format in which one member is randomly assigned to be a leader who has the ultimate decision right, but can consult the two other members by communicating with them. We will call this treatment "*Leader"*-treatment. In the second procedure all members have an equal influence on the team decision. In this format, all members first can communicate with each other and then make an individual choice. The team's decision is the median of the members' choices. Since this procedure is reminiscent of a median voter model, we call it "*Voting*". The leaders' decisions and the median choice are binding for all team members and determine each member's payoff according to Table 1 [A].

In order to gain further insights into what might drive the differences between individuals and teams, we let each of the three team members in *Leader* and *Voting* submit his/her intended choice in each period *before* the communication phase within the team starts. In period 1, these intentions are completely independent from each other since no interaction has taken place at that stage. Hence, we can use the intentions as an indicator of individual preferences and compare them (a) to the individual choices in the *Individuals*-treatment of *WL-BASE* and (b) to the actual choices in *Leader* and *Voting*. The comparison (a) allows to check whether just belonging to a team already changes individuals' (intended) strategies; comparison (b) reveals the influence of the communication within a team.

A total of 180 new subjects participated in six sessions á 30 subjects who interacted for 20 periods, like in *WL-BASE*. The sessions again involved 6 independent groups with 5 players each for both *Leader* and *Voting*. They were run at the University of Cologne and lasted for about 60 minutes each, with subjects earning on average 12€, plus a show-up fee of 2.5€.

Panel [A] in Table 7 presents the main results for *Leader* and *Voting* and relates them to the results reported in sections III and IV for *Individuals* and *Teams* in the *WL-BASE* game. Part [1] shows the average of chosen numbers, actual minima, and profits. They are all significantly higher than in *Individuals*. This shows that teams coordinate more efficiently than individuals also in the two new formats. This is confirmed also in part [2] that presents the previously introduced indicators for the degree of (mis)coordination. Part [3] of Table 7 then presents the EWA-learning estimates for *Leader* and *Voting*. Again, we find that the sensitivity of teams to the previous attractions of different strategies (parameter λ) is significantly larger than for individuals. The combination of parameters δ and ϕ being significantly smaller for teams implies that teams are more likely to play the previous period's choice – even if it did not coincide with the group's minimum. This means that teams are more steadfast in their decision making, while individuals are more likely to reduce their number when they were not choosing the minimum in the previous period.

Table 7: Robustness checks

	[A] *WL-BASE*				[B] *2x2-WL*	
	Indiv.‡	*Teams*‡,#	*Leader*#	*Voting*#	*Indiv.*	*Teams*
	(*N*=90)	(*N*=135)	(*N*=90)	(*N*=90)	(*N*=36)	(*N*=60)
[1] *Average data*						
Numbers 1st period	5.98	6.53 **	6.80 ***	6.83 ***	1.81	1.90
Intentions 1st period	-	-	6.33 ++	6.41 +++	-	-
Numbers overall	4.56	6.09 *	6.44 **	6.96 ***	1.68	1.90
Minima	3.91	5.79 **	6.00 **	6.85 ***	1.64	1.89
Payoffs	92.6	114.9 **	115.6 **	127.4 ***	84.0	88.2
[2] *Coordination*§						
Miscoordination	0.65	0.30 **	0.44	0.11 ***	0.03	0.01
Perfect coordination	0.41	0.69 *	0.72 **	0.94 ***	0.93	0.98
Adjustment	0.60	0.29 *	0.42	0.08 ***	0.05	0.01
[3] *EWA-estimates*†						
λ	4.36	5.84 *	7.83 ***	5.07 ***	6.04	7.45
ϕ	0.72	0.58 ***	0.62 **	0.61	0.79	0.50
δ	0.70	0.73	0.58 *	0.00 ***	0.14	0.25
κ	0.69	0.72	0.00 ***	0.08 ***	0.00	0.00
N(0)	1.29	1.19	0.97	2.25 **	0.53	2.01

‡ data are from Tables 4 to 6.
§ see Table 5 for definitions
† see Section 5 for definitions
**** (**) [*] significant difference to individuals (Indiv.) in WL-BASE at the 1% (5%) [10%] level (Mann-Whitney U-test)*
+++ (++) Intentions are significantly different from actual numbers in respective treatment at the 1% (5%) level (Wilcoxon-signed ranks test). Note that intentions are not significantly different from numbers chosen by individuals (Indiv.).
 # According to a Kruskal-Wallist test, there is no significant difference between the three treatments with teams in WL-BASE.

It is important to note that a Kruskal-Wallis test shows no significant difference in the three treatments with teams in *WL-BASE* (i.e., *Teams, Leader,* and *Voting*) for any variable in parts [1] and [2] of Table 7 and for the parameter λ. This implies that the decision making procedure within teams (unanimous agreement in *Teams*, median voting in *Voting*, or having a leader with ultimate decision making power in *Leader*) does not have any notable impact on our previously established result of teams coordinating more efficiently than individuals.

Asking for the team members' intentions in *Leader* and *Voting* sheds more light on why teams are more efficient than individuals. In the second line of part [1] in Table 7 we report the average *intended* choice. It is not significantly higher than the actually chosen numbers in *Individuals*, suggesting that before any interaction team members' intended choices are not different from individual decision makers' actual choices. However, the intentions of team members are significantly smaller than the actually chosen numbers in *Leaders* as well as *Voting*. This implies that the communication – which takes place after entering intentions, but before making decisions – drives up numbers towards higher efficiency. In an attempt to find out why this is the case, we have used the *Voting*-treatment to tabulate how a team member's intention in period 1 relates to his/her actual choice in this period. Out of the 27 subjects who intended to choose a number below "7", zero of them have chosen a number below their intention, seven have implemented their intention, and 20 have chosen a higher number than originally intended. This pattern is significantly different from random ($p < 0.01$, χ^2-test). Out of 63 subjects with an intention to pick "7", 59 have chosen "7" and only four have picked a lower number (which is also significantly different from a random choice; $p < 0.01$, χ^2-test). The same general pattern is observed in *Leader* where seven out of the eight leaders who intended a lower number than "7" have picked a higher number, while 21 out of the 22 leaders with the intention of choosing "7" have done so.

Overall, the analysis of intentions versus actual choice in period 1 reveals that team members who want to choose the most efficient number "7" are more steadfast in their decisions, suggesting that they have a stickier prior and thus a greater influence on the team's decision. This drives up the chosen numbers towards the payoff-dominant choice.

B. Coordination of Individuals and Teams in a 2x2-Game

The difference between individuals and teams might be due to the teams coping more successfully with the strategic uncertainty arising from the many possible choices of four other decision makers, as conjectured by another referee. Hence, reducing the number of players and the number of pure strategies available to the players might diminish the superiority of team decision making. Since much of the literature on coordination games is built on simple 2x2-games, we use the one employed by Charness and Jackson (2007) to compare individual and team behavior in such a comparatively simpler environment than the games studied so far in this paper. Table 8 shows the payoffs in the game. Payoff dominance suggests the choice of "2", while risk dominance would imply choosing "1". The game was played for 20 periods with 18 pairs of two individuals, and 10 pairs of 2 teams with three subjects each. The decision making procedure in teams was exactly the same as in the treatments reported in Section II. The sessions were run with 96 new subjects at the University of Innsbruck and took about 30 minutes (for individuals) to 50 minutes (for teams), with participants earning on average 8.8€, plus a show-up fee of 2.5€.

Table 8: Payoffs in the 2x2-game

	Smallest number in group	
Own number	**2**	**1**
2	90	10
1		80

The right-hand side of Table 7 presents the main results for individuals and teams. Overall, individuals do already very well, with 68% of individuals choosing "2". Teams do better, with 90% choosing "2", but the difference fails significance. Indeed, Table 7 reveals that on average teams are more efficient in coordination in each single indicator presented in parts [1] and [2], but all indicators are not significant at conventional levels according to a Mann-Whitney U-test.[15] This is mainly due to individuals coordinating already pretty efficiently, leaving almost no room for teams to do better. The EWA-estimations in part [3] show a higher λ and δ for teams, albeit again insignificant.

Overall, our results for the 2x2-game imply that with only two decision-makers there is no significant difference between individuals and teams, although teams are on average slightly more efficient in coordination. Hence, the number of players seems to be important for the differences detected between individuals and teams in all other games reported above, which is an important finding of this robustness test.[16] Individuals are good in coordinating efficiently when strategic uncertainty is low due to only one other player being involved. Teams are successful in coordinating more efficiently even when the number of interacting players is not minimal, i.e., when it is larger than two.

VI. Relation to the Literature on Team Decision Making

Team decisions have been found to be closer to standard game theoretic predictions (assuming selfishness and rationality) than individual decisions in a variety of games. For example, teams have been found to send and accept smaller transfers in the ultimatum game (Bornstein and Ilan Yaniv, 1998) and to be less generous in the dictator game (Wolfgang Luhan, Martin G. Kocher

15 A less conservative two-sample t-test with equal variances reveals weakly significant differences between individuals and teams for payoffs, miscoordination, and perfect coordination (with $p = 0.09$ in all cases).

16 Van Huyck et al. (1990) show that individuals coordinate very efficiently when only two players are paired with each other – even when both players have seven strategies available as in *WL-BASE*. Hence, from their result it seems to follow that the number of players is the crucial feature in our robustness check in the 2x2-game.

and Matthias Sutter, 2009).[17] Teams send or return smaller amounts in the trust game (James C. Cox, 2002, Tamar Kugler et al., 2007) and exit the centipede game at earlier stages (Bornstein, Kugler and Anthony Ziegelmeyer, 2004). They converge quicker to the equilibrium in guessing games (Kocher and Sutter, 2005) and play more often strategically in signaling games (Cooper and John H. Kagel, 2005).

One way to organize the evidence from the various games (like ultimatum, dictator, trust, centipede, beauty-contest, or signaling games) is that team decisions are more driven by a concern for monetary payoffs than individual decisions. A recent paper by Charness, Luca Rigotti and Aldo Rustichini (2007) has shed light on the reasons for this effect. They have found in a prisoner's dilemma game as well as a coordination game that the mere fact of becoming a group member lets subjects shift their individual decisions towards those that are more profitable for the group. Charness et al. (2007) note that being responsible for another subject's payoffs leads individuals to choose strategies with higher payoffs more often. The same has been found in this paper in the *Leader*-treatment where leaders have made more efficient decisions (for themselves and the other two team members) than individuals have done in the *Individuals*-treatment. It is noteworthy in comparison to Charness et al. (2007), though, that we have observed this membership effect only *after* interaction has taken place within the team through communication in the chat. In addition to this group membership-effect we have found that teams care more for higher payoffs (both when making decisions via mutual agreement or via voting). The importance of payoff-dominance for the differences between individuals and teams has also been confirmed by the EWA learning model.

Summing up, our paper contributes to the literature on team decision making in the following ways: First, it fills the gap of analyzing behavior of teams in coordination games. Contrary to the existing literature, coordination games involve the issue of selecting among multiple equilibria, a task which has not been examined with teams so far. Second, this paper provides a thorough analysis of learning of teams and compares it to learning of individuals.[18] Third, it examines three different formats of team decision making (unanimous agreement, median voting, and having a leader with ultimate decision power).

[17] The paper by Tim Cason and Vai-Lam Mui (1997) is often misinterpreted as showing that teams are more generous than individuals in a dictator game. However, Cason and Mui (1997) did not find that teams in general are more generous than individuals, but only reported more other-regarding team choices when team members differed in their individual dictator game choices.

[18] Ho et al. (2007) have applied the self-tuning EWA model to examine Kocher and Sutter's (2005) data on team decision data in a beauty-contest game. We are not aware of any other attempt to study how teams learn in comparison to individuals.

VII. Conclusion

In this paper we have presented a large-scale experiment on coordination games with a total of 1,101 participants. The bottom line of our findings is that teams are remarkably better in achieving efficient outcomes and avoiding miscoordination in games with multiple equilibria. Only when payoff-dominance does not apply as an equilibrium selection device (as in *AO-RISK*) or when the number of players and available strategies is minimal (as in the 2x2-game) then the differences between individuals and teams are not significant. In all other games we have found teams to be significantly better in coordinating on more efficient outcomes. Communication and the stickier priors of team members who intend to choose the most efficient numbers have been identified as driving forces for the higher efficiency of teams in the treatments *Leader* and *Voting*. Applying the experience weighted attraction (EWA) learning model of Camerer and Ho (1999) to our data has revealed an important difference in the learning of individuals and teams in coordination games. The EWA-model shows that teams are much more sensitive to the attractions of different strategies. Since more profitable strategies get higher attractions, team decisions are more heavily influenced by monetary considerations than individual decisions. Furthermore, teams are steadfast in trying to achieve an efficient outcome, and they are much more successful in strictly best-responding (ex post) to what other teams do.

These findings add a novel, and hitherto overlooked, dimension to the recently flourishing literature on how efficient outcomes can be achieved in coordination games. Previous studies have identified several factors that facilitate successful and efficient coordination (among individuals). From an organizational point of view, the use of financial incentives (Brandts and Cooper, 2006a, Hamman et al., 2007), communication (Blume and Ortmann, 2007) or slowly managed growth (Weber, 2006) may be considered the most important of these factors. We have determined team decision making as another major factor. Hence, the almost universal practice of firms and organizations to set up work teams inside an organization and even in networks between organizations can be considered an appropriate means to enhance efficient interactions.

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Supplementary material accompanying “Efficiency gains from team-based coordination – Large-scale experimental evidence”

Supplement A) Experimental instructions

We provide a translation (from German) of the instructions for game WL-BASE in the teams-treatment. The instructions for all other games and treatments were analogous. The complete set of instructions is available upon request.

Welcome to the experiment. Please do not talk to other participants until the experiment is completely over. In case you have questions, please raise your hand and an experimenter will assist you.

Number of periods and decision-making units

- This experiment has 20 periods.

- There will be units of 15 participants each. You will only interact with members of the unit to which you are assigned throughout the whole experiment. Neither during nor after the experiment will you be informed of the identities of other members in your unit.

Teams

- Within each unit there will be Teams of 3 subjects each. That means that each unit will have 5 teams. Teams will stay together for the entire experiment.

- Members of a given team will have to agree on a single decision for the whole team. To do so, members can exchange messages through an instant messaging system at the bottom of their screens. As soon as you press “Return” after having written a message, it will be visible on the two other members’ screens. You are allowed to send any message you like, except for those revealing your identity and except for using abusive language.
  If a team has agreed on a joint decision, each member has to enter this decision on his/her screen. In case the three entries are not identical, a team can go back to use the instant messaging system to agree on a joint decision. Then team members can enter the team’s decision a second time. Note that a team that does not manage to enter a joint decision at that stage will not get any payoff for the respective period. If one team within a unit fails to enter a joint decision of all three members, then this team will not be considered in the determination of the outcome for the other teams.

Sequence of actions within a period

- **Choosing a number**

  Each team has to choose a single number from the set {1, 2, 3, 4, 5, 6, 7}. Teams have to decide independently of other teams. After all teams have entered their number, you be informed about the smallest number chosen by any team in your unit (including your own team).

- **Period payoff**

  Your payoff (in Talers) depends on your own number (i.e., the number of your team) and the smallest number chosen by any team within your unit. The payoffs per member of a team are given in the following table.

Payoff table (per team member)

Your number	Smallest number in unit						
	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

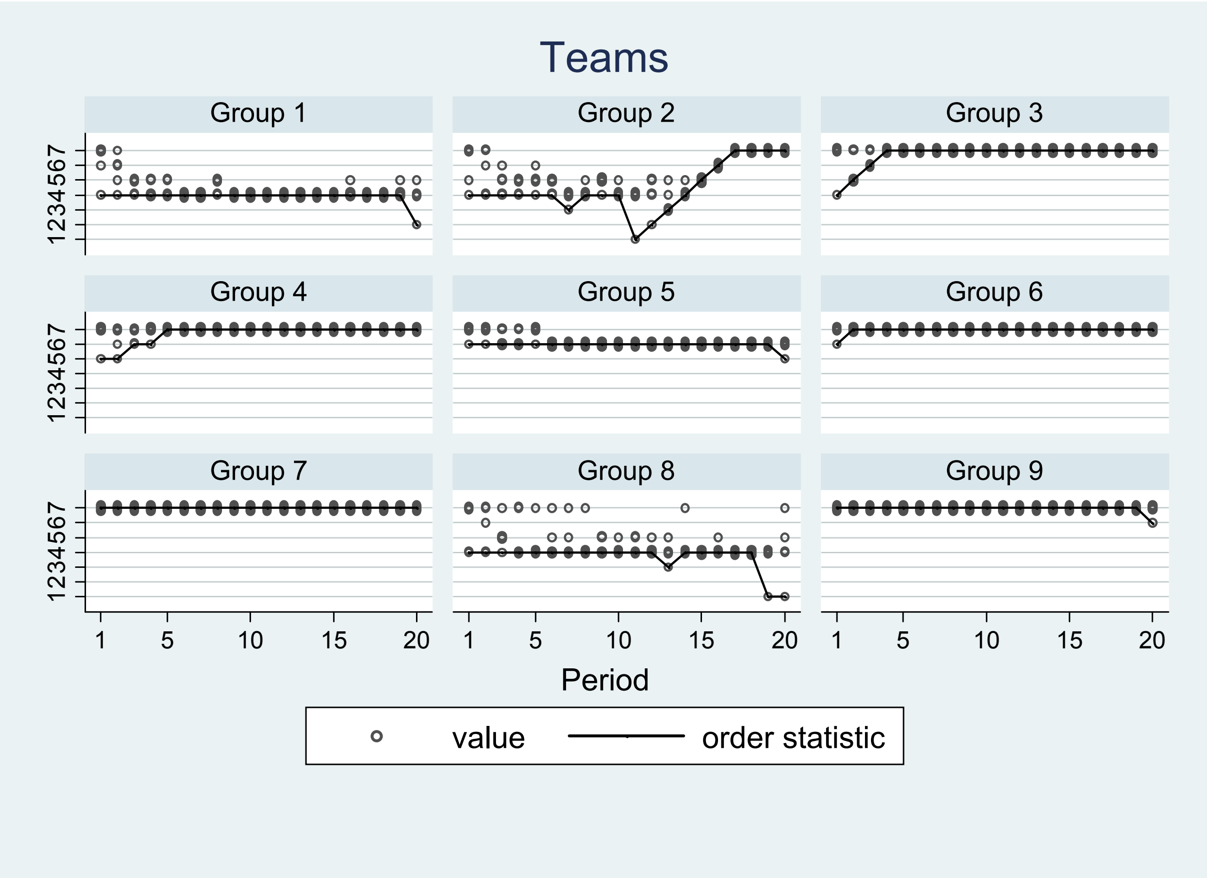
Total earnings

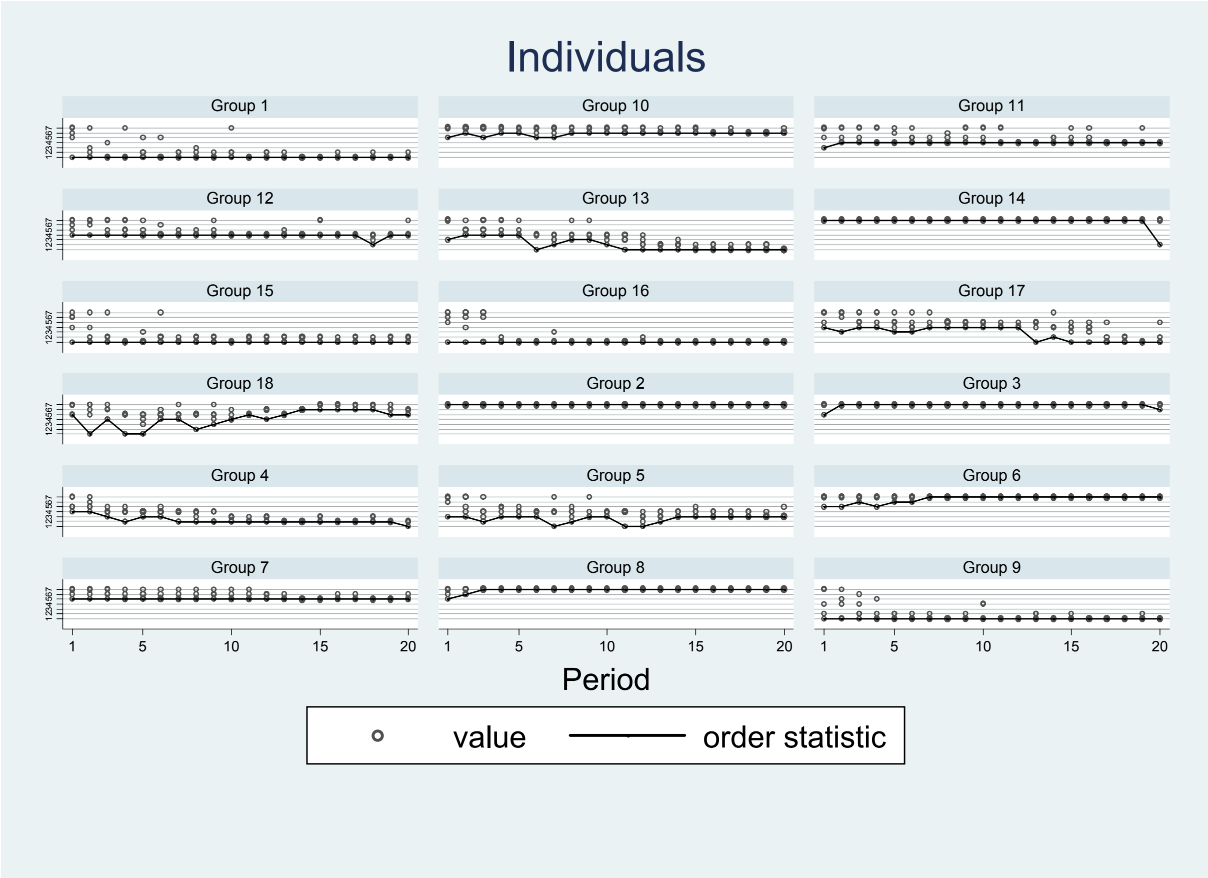
- The earnings of each period are accumulated and exchanged at the end of the experiment as follows: **200 Taler = 1€.** Each participant will receive his total earnings privately and confidentially. In addition to your earnings from the experiment, you will receive a **show-up fee of 2.50€**.

Supplement B) Raw data

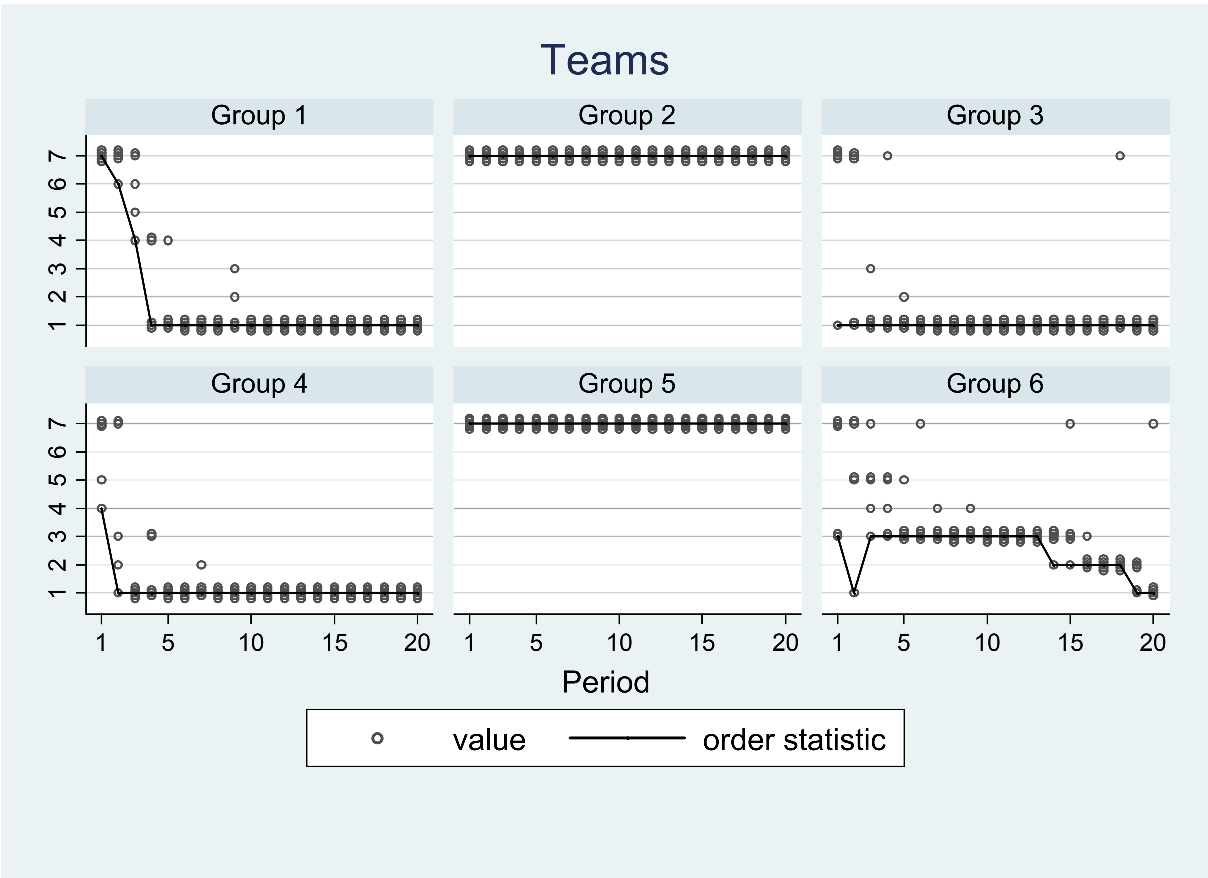
Multiple entries of a given number are indicated by jittering

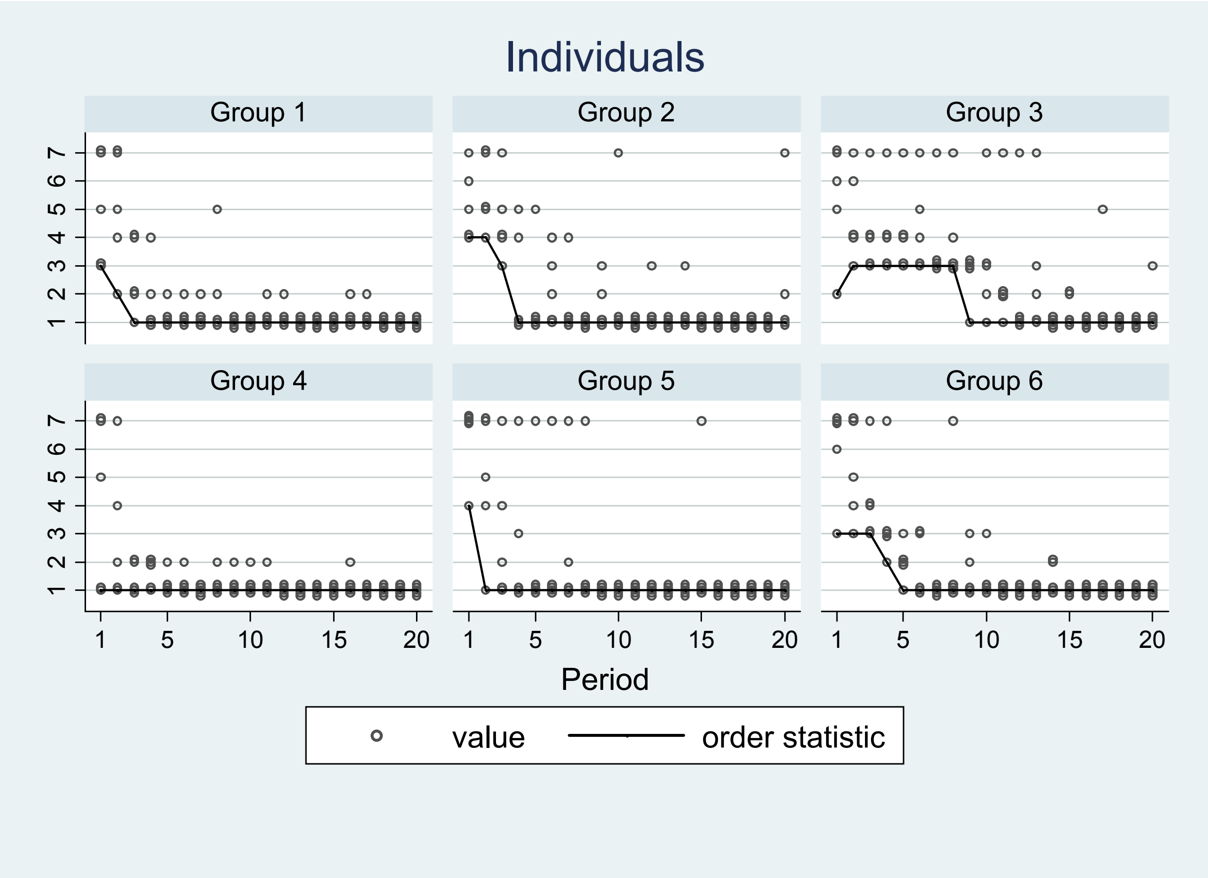
WL-BASE



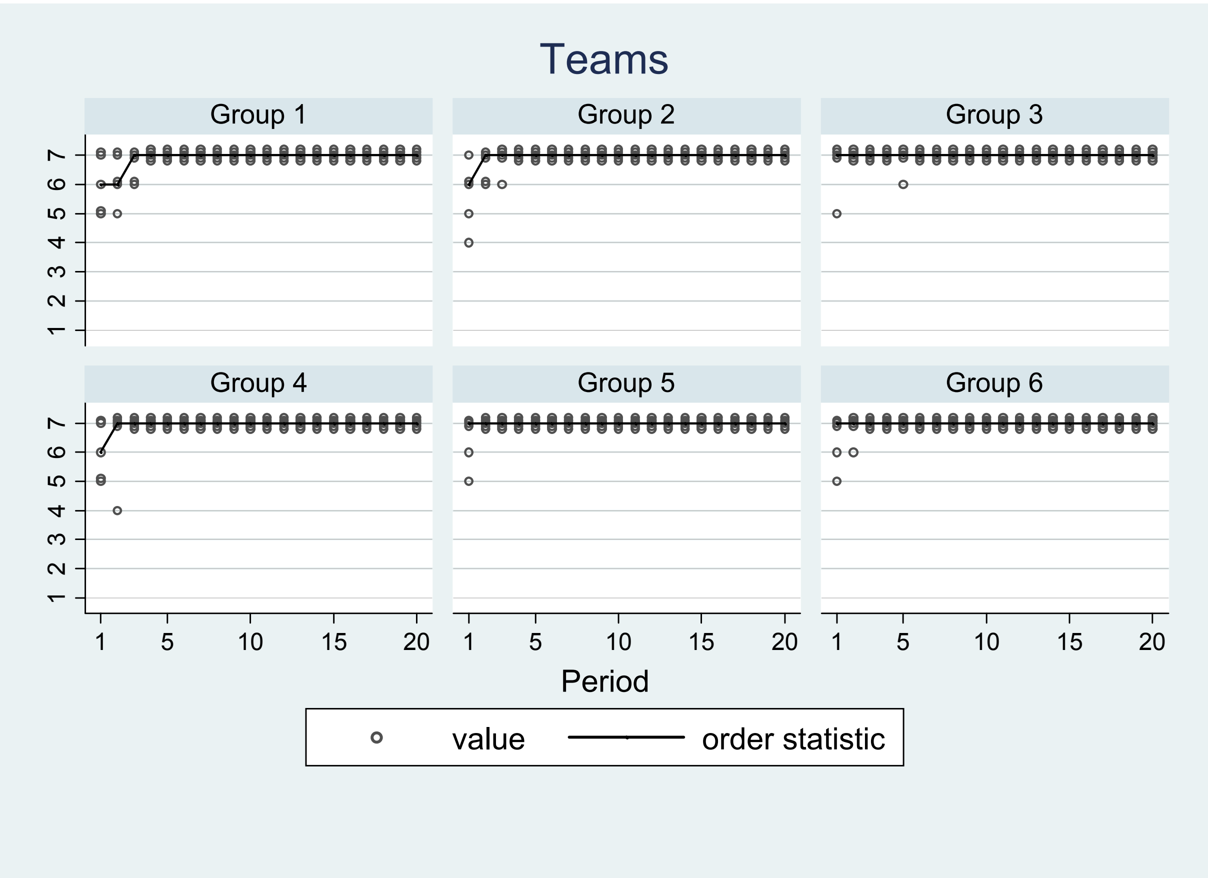

Individuals
Group 1
Group 10
Group 11
Group 12
Group 13
Group 14
Group 15
Group 16
Group 17
Group 18
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
1 5 10 15 20
Period
value
order statistic

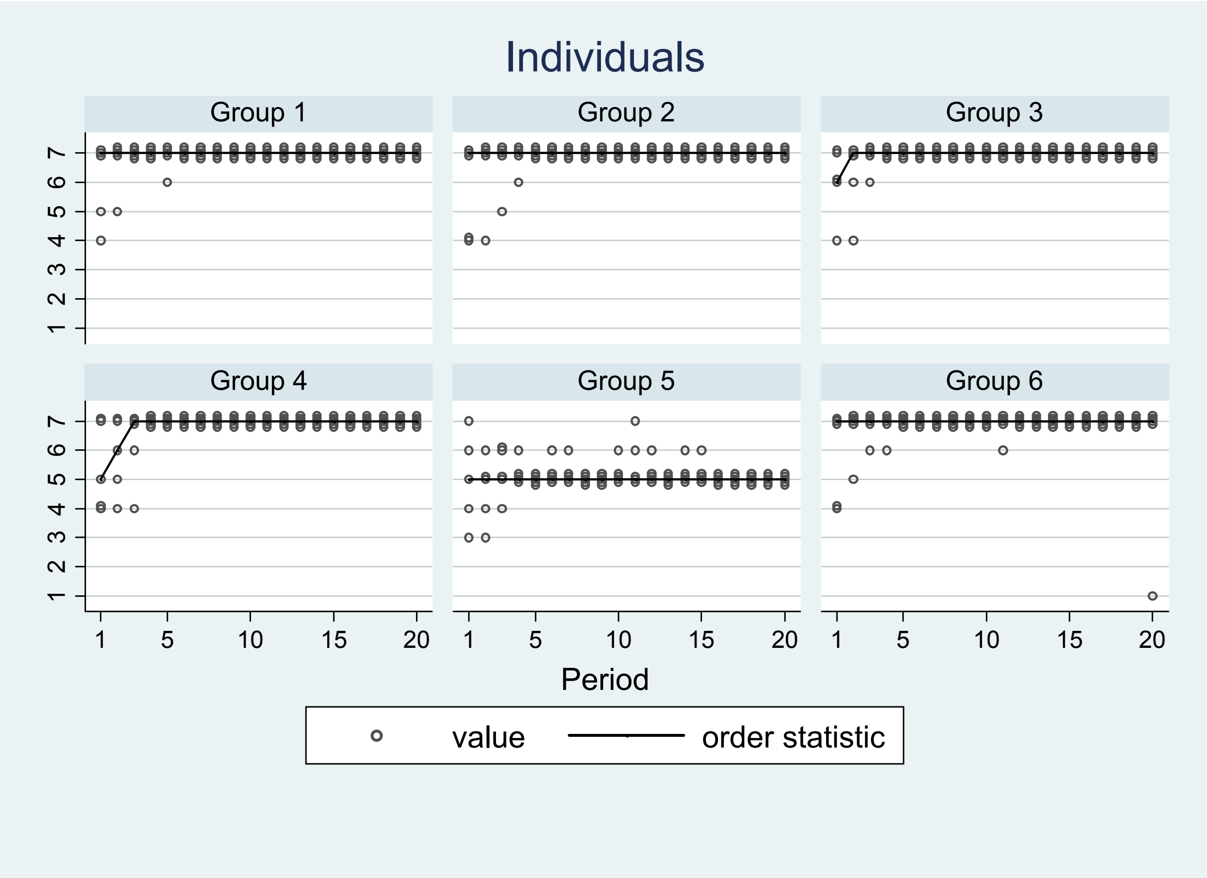
WL-RISK


Teams
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
1 2 3 4 5 6 7
1 5 10 15 20
Period
value
order statistic

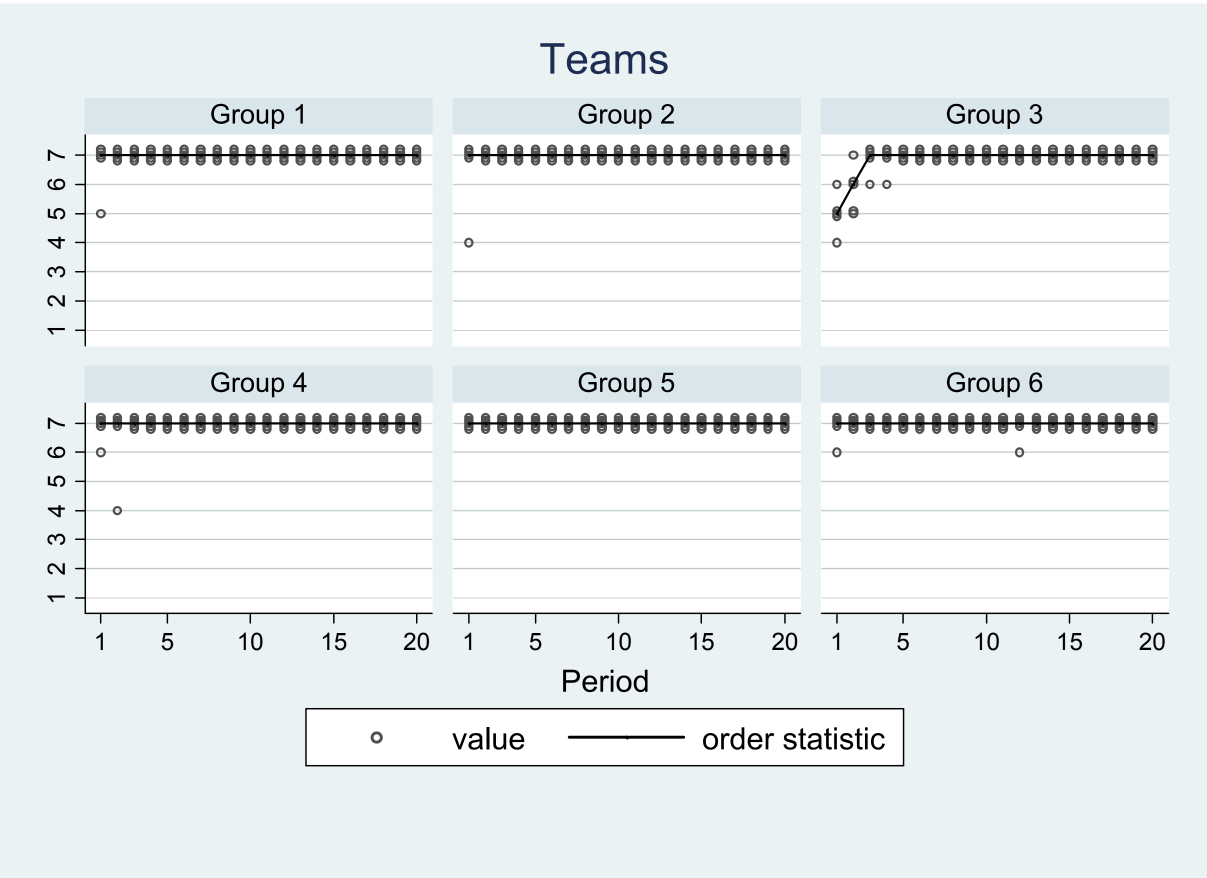

Individuals
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
1 2 3 4 5 6 7
1 5 10 15 20
Period
value
order statistic

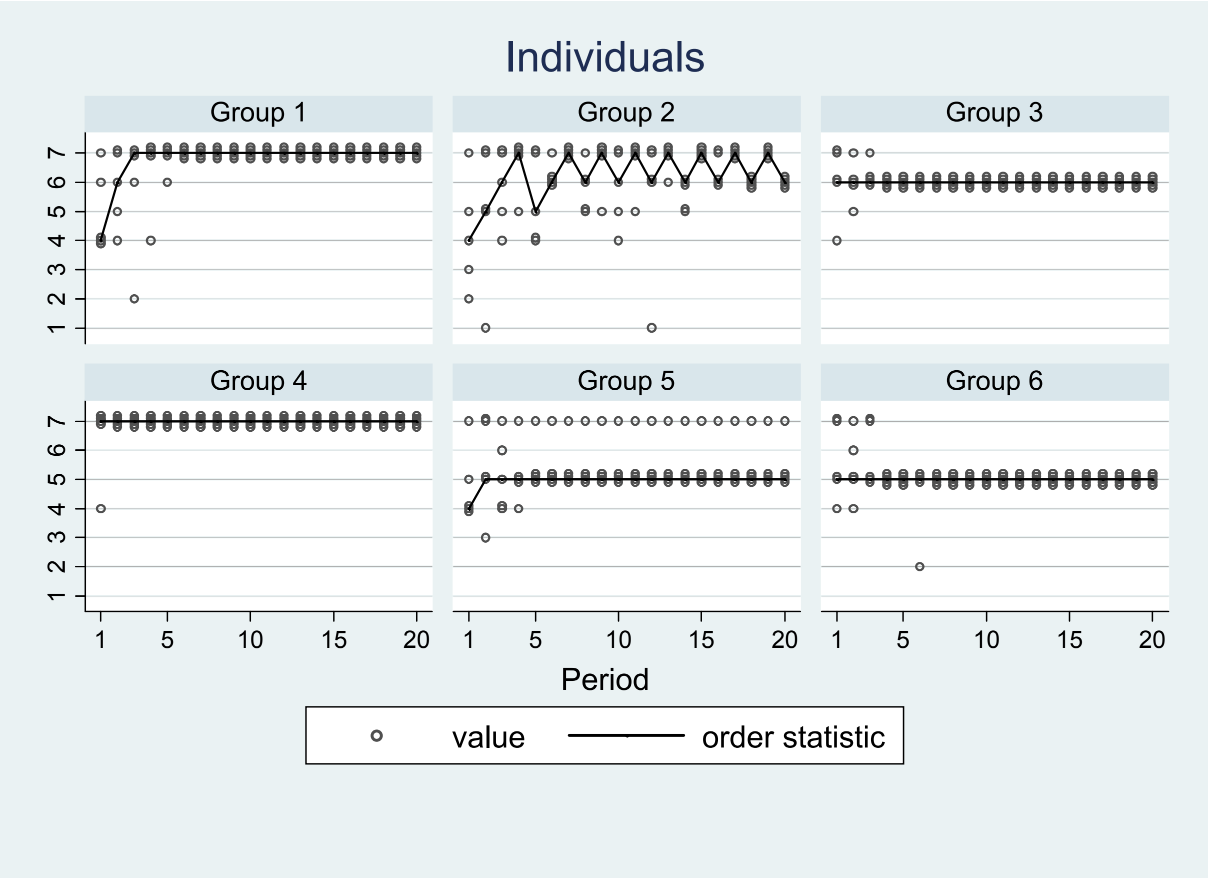
AO-BASE


Teams
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
1 2 3 4 5 6 7
1 5 10 15 20
Period
value
order statistic

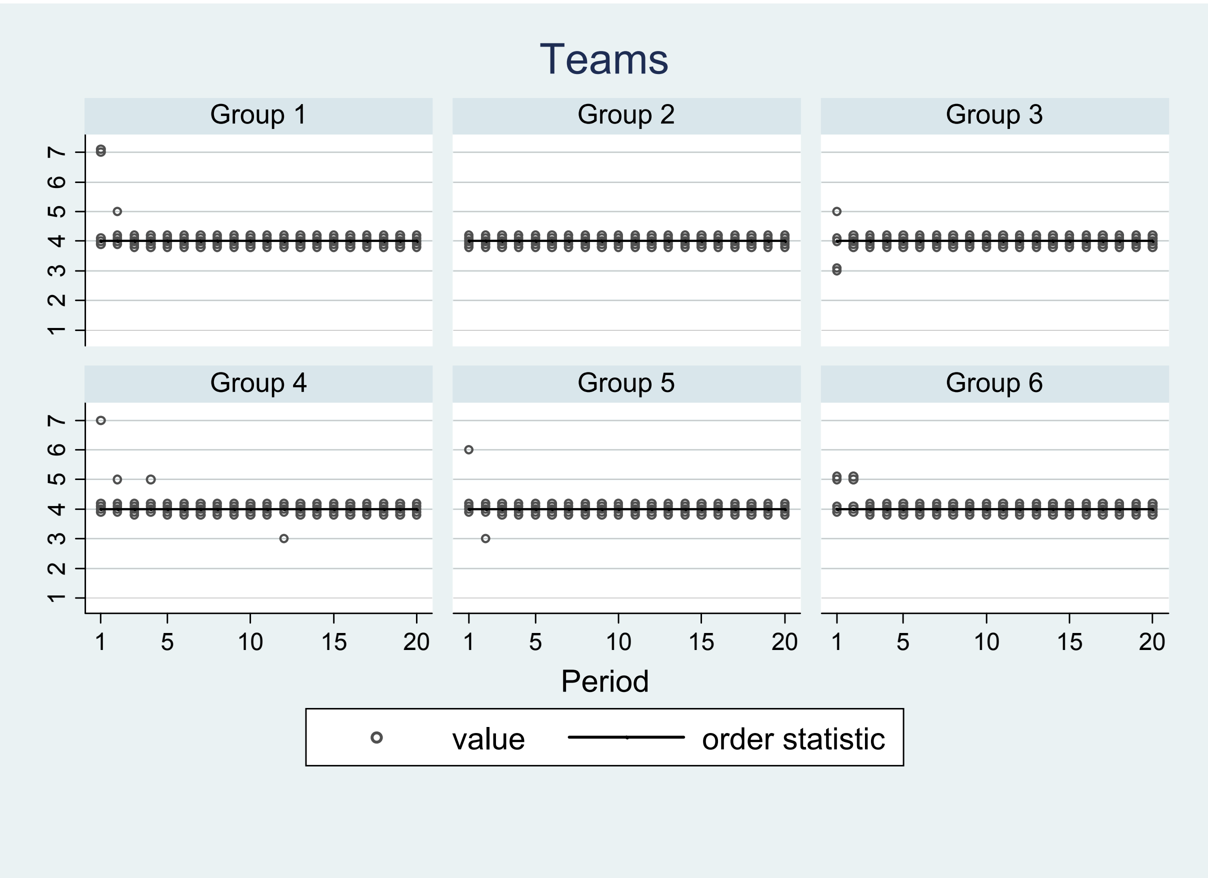

Individuals
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Period
value
order statistic

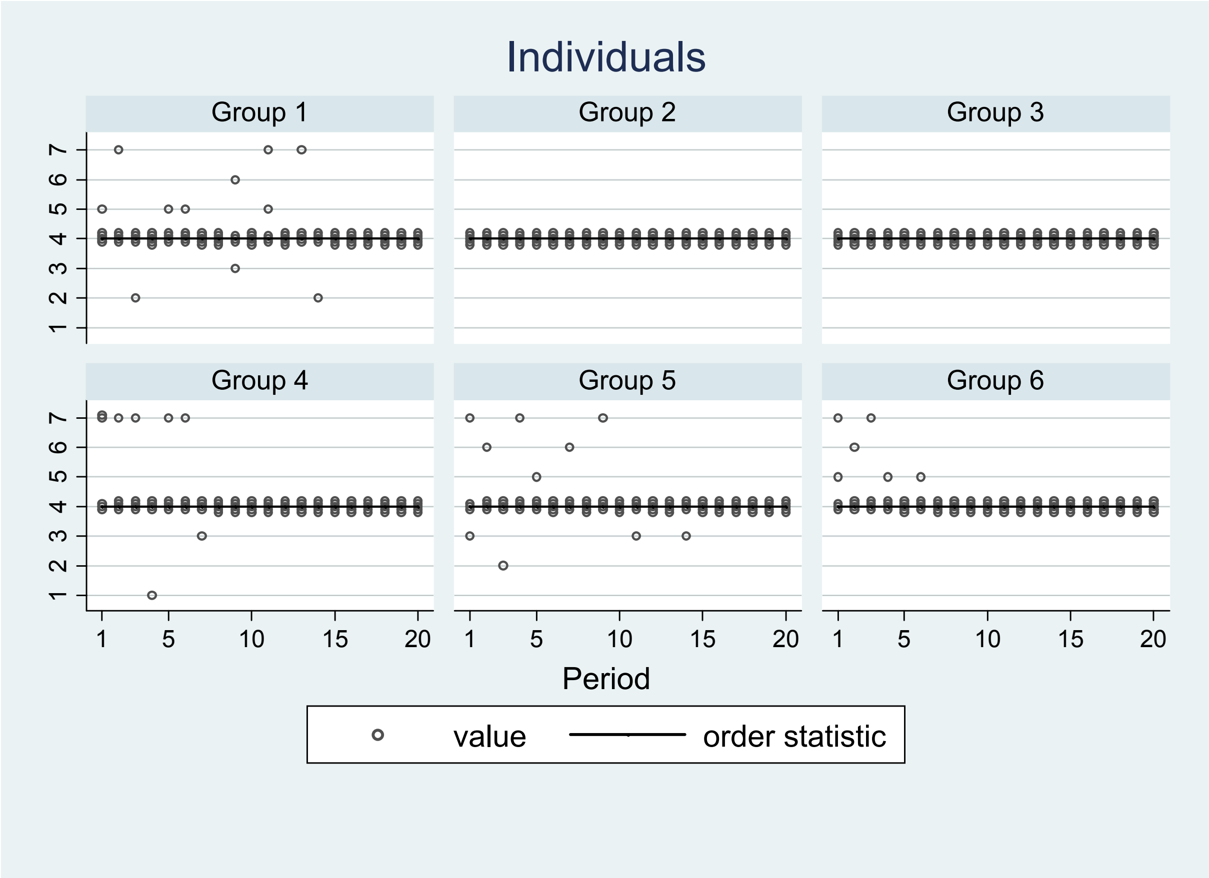
AO-PAY


Teams
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Period
value
order statistic

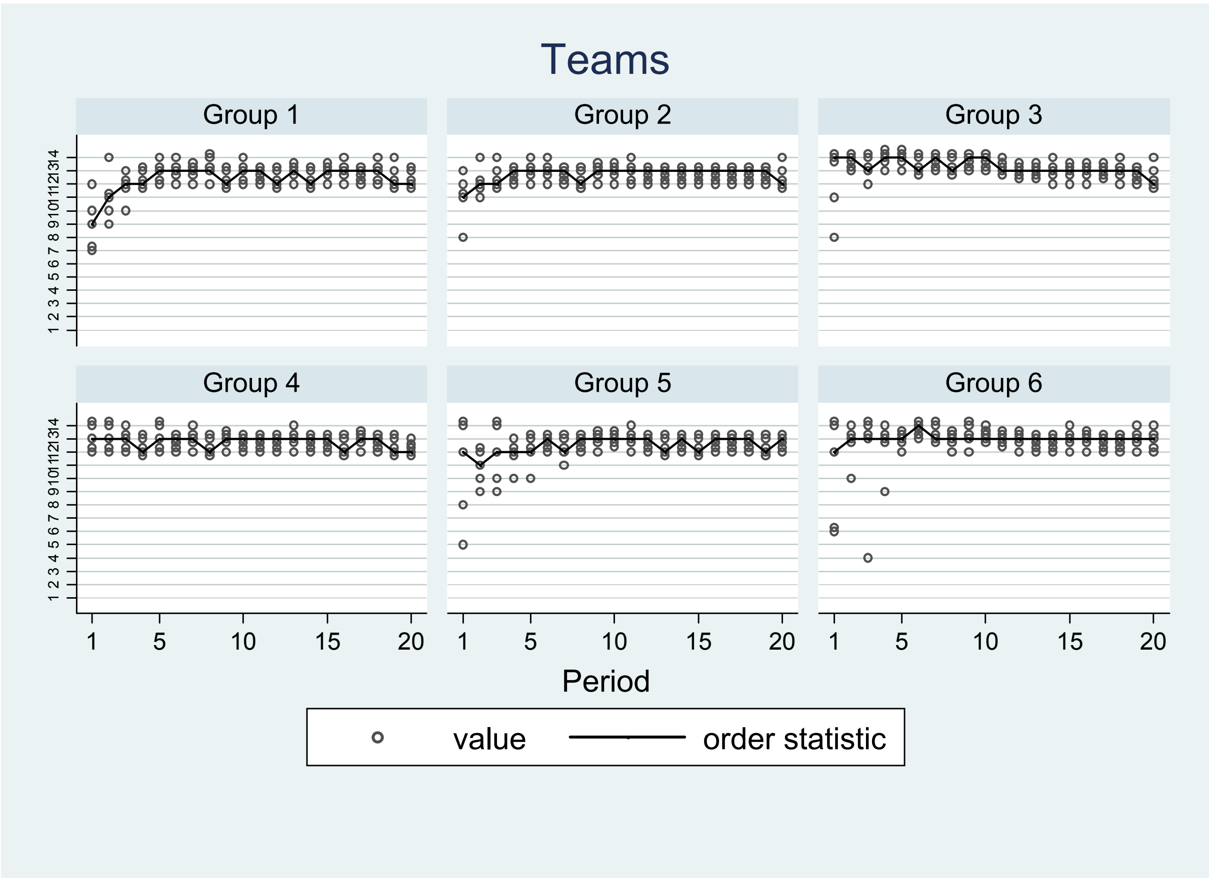

Individuals
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
1 2 3 4 5 6 7
1 5 10 15 20
Period
value
order statistic

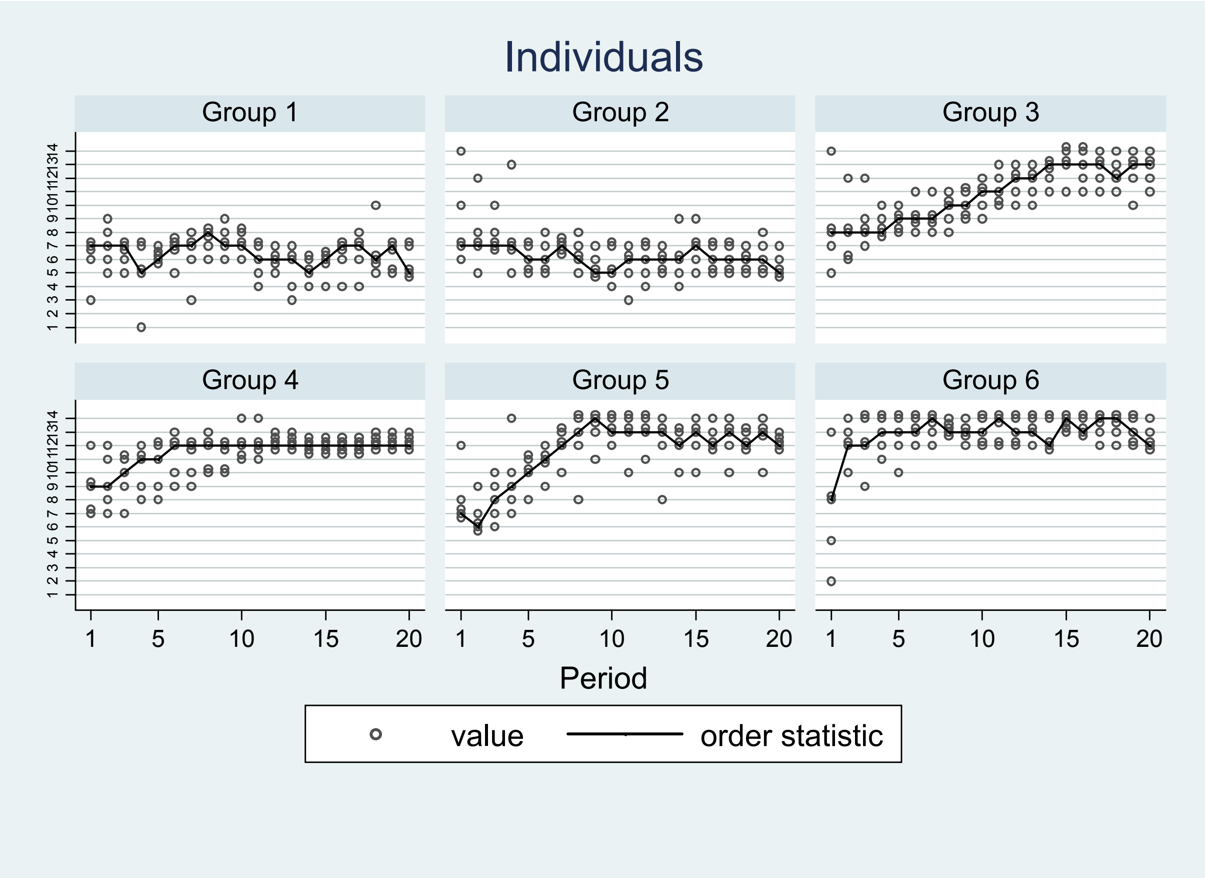
AO-RISK


Teams
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
1 2 3 4 5 6 7
1 5 10 15 20
Period
value
order statistic


Individuals
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Period
value
order statistic

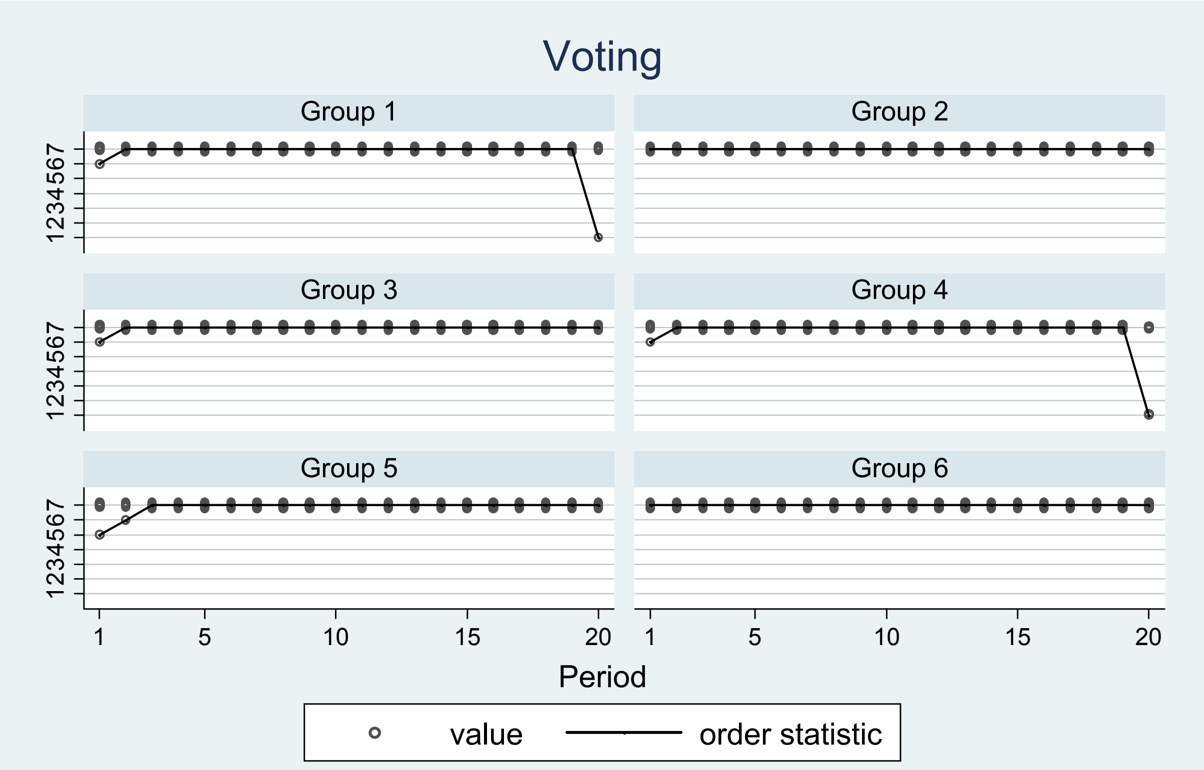
SEPARATRIX

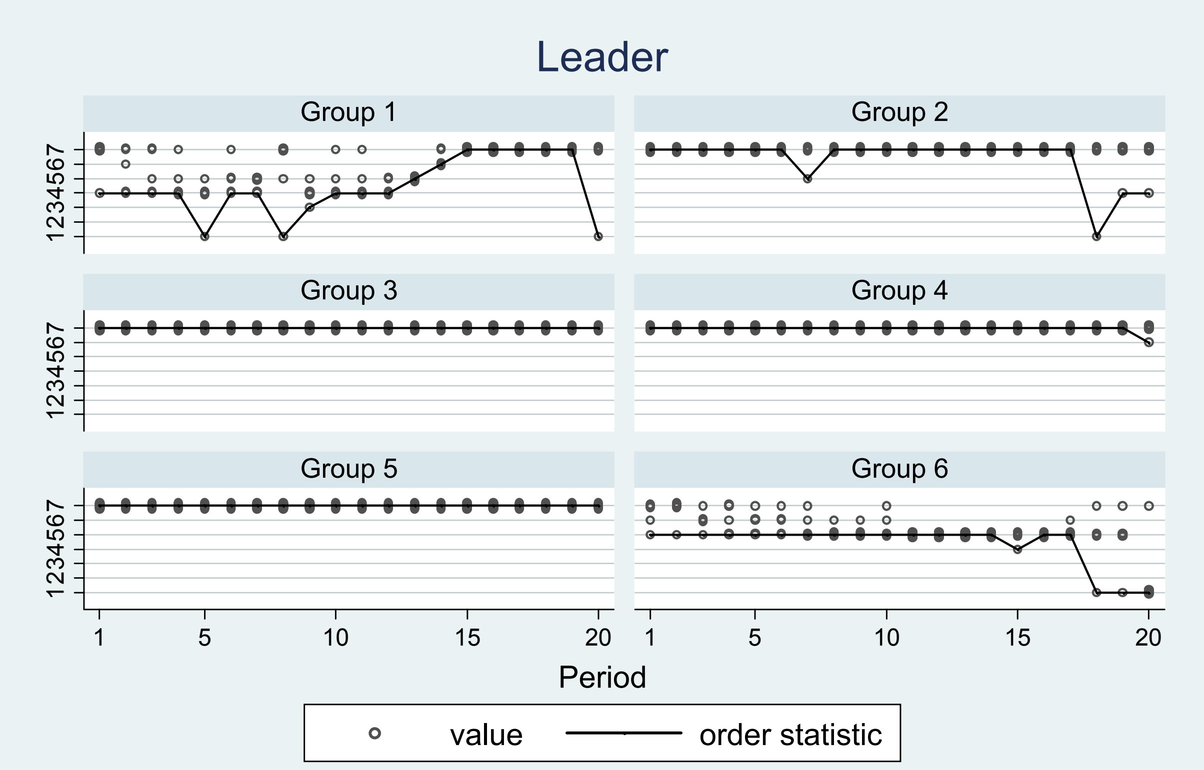

Teams
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Period
value
order statistic



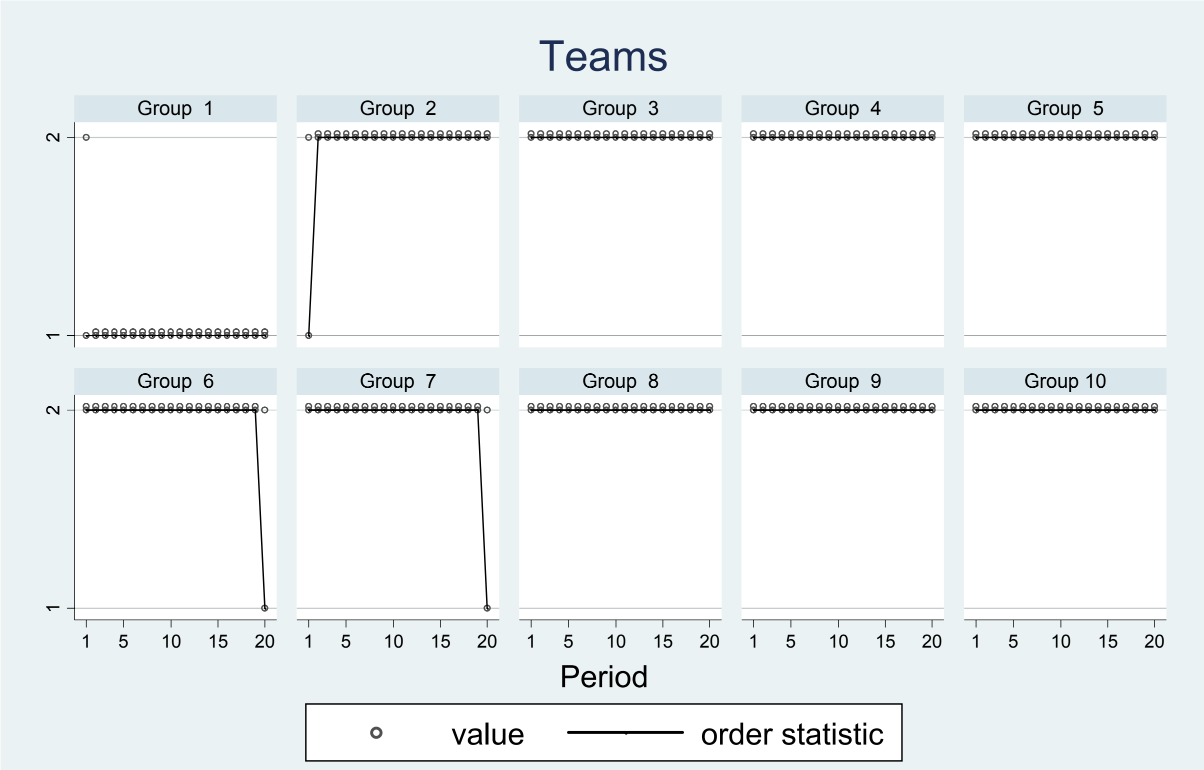
Individuals
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
1 2 3 4 5 6 7 8 9 10 11 12 13 14
1 5 10 15 20
Period
value
order statistic

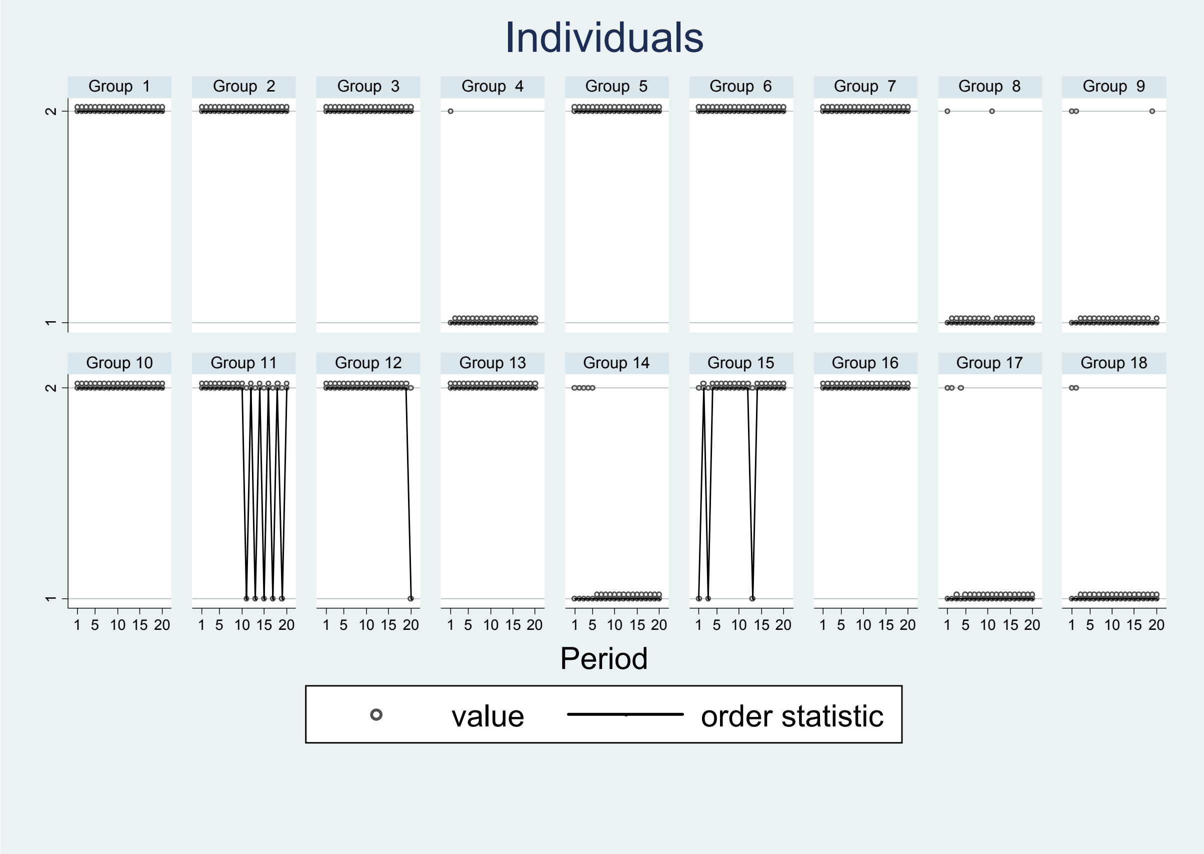
WL-BASE – Voting and Leader





2x2 GAME


Teams
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
Group 10
1
2
1 5 10 15 20
Period
value
order statistic


Individuals
Group 1
Group 2
Group 3
Group 4
Group 5
Group 6
Group 7
Group 8
Group 9
Group 10
Group 11
Group 12
Group 13
Group 14
Group 15
Group 16
Group 17
Group 18
1
2
1 5 10 15 20
Period
value
order statistic