The role of payoffs associated with partial coordination in laboratory coordination games

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Abstract This paper presents experimental evidence on coordination games with two Pareto-rankable equilibria: one payoff-dominant and the other secure. Through experiments conducted with Indiana University undergraduates, I examine the effect of varying the difference in payoffs between strategies in cases of partial coordination, in which some but not all of the other members of a given player's group select the payoff-dominant strategy. I find that in repeated games players do not respond to changes in payoffs associated with partial coordination and consistently choose the payoff-dominant strategy. In one-shot games, however, payoff dominance is less salient when payoffs associated with partial coordination favor the secure strategy than when payoffs associated with partial coordination are the same for each strategy.

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1 Introduction

Many economic models find agents trying to coordinate their decisions in the presence of multiple, Pareto-rankable equilibria.[1] Two commonly used conventions, or selection criteria, that agents use to coordinate their decisions are payoff dominance and security. In coordination games with a distinct payoff-dominant strategy and secure strategy, an agent chooses among the two strategies based on which strategy she predicts other agents will choose. The Pareto-optimal equilibrium, which maximizes each agent's private payoff, occurs when all agents select the payoff-dominant strategy. However, if agents face uncertainty regarding which strategies other agents will select, they may opt alternatively for the secure strategy, which provides a higher minimum payoff than the payoff-dominant strategy. Given that there may be reason to believe not all agents will select the payoff-dominant strategy, agents may be interested not just in payoffs in instances of complete coordination on the Pareto-optimal equilibrium, but also in instances of partial coordination, in which some but not all other agents select the payoff-dominant strategy. This paper reports on a series of three-player laboratory coordination games designed to examine how changes in the difference in payoffs between strategies in instances of partial coordination influence agents' coordination on the Pareto-optimal equilibrium.[2]

Consider the payoff matrices in Table 1. These matrices provide the payoff a player will receive for selecting one of two strategies, 0 or 1, given a set of decisions from the two other

[1]Multiple equilibria may arise in a number of contexts. An earlier version of this paper was motivated by discussion of multiple equilibrium formation caused by positive network externalities, in which the payoffs for engaging in an activity depend positively on the number of other agents who engage in the same activity. As an illustrative example, consider Andvig and Moene's (1990) model of corruption, in which government officials select one of two strategies: to be corrupt or to be honest. Positive network externalities exist for both strategies. It pays for a given official to be corrupt if a sufficient number of other officials are corrupt, and similarly, the payoff for choosing to be honest increases with the frequency of other honest officials. The model may be specified such that officials receive a higher payoff when they have coordinated on the *all honest* equilibrium than they receive if they coordinate on the *all corrupt* equilibrium but the payoff for being honest when few other officials are honest is less than the payoff for being corrupt when few other officials are corrupt. The dilemma facing officials in this "corruption game" arises from the classic trade-off between risk and return. An official must balance the potentially high potential payoffs associated with choosing honesty with the risk that other officials will choose not to be honest.

[2]Three was chosen because it represents the lowest number of players necessary to meaningfully examine partial coordination and, as a result, provides a logical starting point for research.

players in her group.[3] In both matrices, 1 is the payoff-dominant strategy. The alternative strategy, 0, is said to be secure, since it provides a higher payoff in the worst-case scenario than the payoff-dominant strategy.[4] In both payoff matrices, there is a secure equilibrium, which occurs when all players select 0, and a payoff-dominant equilibrium, which occurs when all players select 1. The matrices differ in the payoffs associated with partial coordination, where only one of the other group members selects 1 (represented by the middle column of the matrix). In Payoff Matrix A, both strategies provide the same payoff for a given player when only one of the other members of her group selects 1. In Payoff Matrix B, however, 0 provides a higher payoff than 1 in instances of partial coordination. This paper asks whether players in treatments employing these two matrices differ in their tendency to play the payoff-dominant strategy.

Harsanyi and Selten (1988) suggest that in games where payoff-dominance and security are in conflict, as in the coordination games studied in this paper, players should "trust" one another to play the payoff-dominant strategy. However, previous experimental research casts doubt on the salience of payoff dominance and finds that coordination failure is common when there exist multiple, Pareto-rankable equilibria. In a pioneering series of papers, Van Huyck, Battalio and Beil (1990, 1991) report on coordination games with 14-16 players and seven Pareto-ranked equilibria, which include one payoff-dominant equilibrium and one secure equilibrium. They find that while first-round play does not clearly favor either payoff dominance or security, security eventually dominates and groups tend to collapse to the (Pareto-inferior) secure equilibrium. Replications with different numbers of players and different numbers of available strategies find similarly inefficient outcomes (Brandts and Cooper, 2004, 2006; Cachon and Camerer, 1996; Schmidt et al., 2003; Van Huyck, Battalio

[3]Table 1 presents the payoff matrices in the same form that they were presented to subjects. The top row of the matrix is labeled "sum of other group members' decisions" instead of, as past studies have done, "number of other players selecting 1" or "number of other players selecting 0" in order to avoid biasing subjects toward one strategy over the other. Giving the strategies the numeric labels "0" and "1," as opposed to, say, "A" or "B," allows for this specification.

[4]This definition of security follows the convention in the experimental economics literature (e.g., Van Huyck, Battalio and Beil, 1990, 1991) to define the maximin strategy (Von Neumann and Morgenstern, 1972) as secure.

and Beil, 1990).

The experimental literature also reports on the extent to which the number of rounds in which a game is repeated influences the salience of payoff dominance and security. Several experiments suggest that repeated interaction among the same group of players increases the likelihood of convergence to the payoff-dominant equilibrium, either because of learning effects or, perhaps more likely, signaling (see, e.g., Clark and Sefton, 2001). Berninghaus and Erhart (1998) examine the effect of increasing the number of rounds from 10 to 30 to 90 in two- and three-player coordination games. They find that increasing repetitions is efficiency-enhancing, though first-round decisions are unaffected.

The present analysis extends the literature by examining the role of payoffs associated with partial coordination on the Pareto-optimal equilibrium in agents' balancing of payoff dominance and security, both in one-shot and repeated protocols. I focus on two sets of treatments: one employing Payoff Matrix A, in which payoffs associated with partial coordination are the same between the two available strategies, and another employing Payoff Matrix B, in which the payoff for selecting the payoff-dominant strategy is less than the payoff for selecting the secure strategy in instances of partial coordination. I find that in repeated games, players almost universally coordinate on the payoff-dominant equilibrium—beginning in round one—across both sets of treatments. In one-shot games, however, players tend to play the payoff-dominant strategy significantly less often when the secure strategy yields a higher payoff than the payoff-dominant strategy in instances of partial coordination. Across all treatments, the payoff-dominant strategy is selected the majority of the time.

2 The experiment

2.1 Game design and conjectures

The experiments discussed here comprise four treatments, outlined in Table 2. ONEA (ONEB) employs Payoff Matrix A (Payoff Matrix B) in a one-shot protocol. REPA (REPB) employs Payoff Matrix A (Payoff Matrix B) in a 15-round fixed-match protocol.

In each of these treatments, a given player selects her strategy based on her predictions about what strategy other players will select and the payoffs she would receive for each strategy if her predictions were realized. This simple intuition can be formulated mathematically as the *expected payoff differential*, given below, between choosing 0 and 1:

$$\sum_{s_{-i}} (u_i(s_i = 1 \mid s_{-i}) - u_i(s_i = 0 \mid s_{-i})) \Pr(s_{-i})$$

Here, u_i is the payoff for a given player i; s_i is the strategy (0 or 1) player i selects; s_{-i} is a set of other two group members' decisions, which belongs to the set $\{(1,1),(1,0),(0,1),(0,0)\}$; and $\Pr(s_{-i})$ is the probability with which player i predicts a given set of other group members' decisions s_{-i} will occur. Suppose player i is risk-neutral. If her expected payoff differential is positive—that is, if, given player i's predictions regarding other group members' decisions, she anticipates that she will earn more by selecting 1 than by selecting 0—player i will select the payoff-dominant strategy. If it is negative, she will opt instead for the secure strategy.

The payoffs, u_i, in the formula for expected payoff differential are given by the payoff matrix, while the probability assigned to each of the possible sets of other group members' decisions is determined by the players themselves. Players must assess the likelihood of three possible sets of other group members' decisions, which are given in the top row of the payoff matrix as sums: (i) both of the other group members select the payoff-dominant strategy ($s_{-i} = (1,1)$); (ii) one of the other group members selects the payoff-dominant strategy and one of the other group members selects the secure strategy ($s_{-i} \in \{(1,0),(0,1)\}$); or (iii) both of the other group members select the secure strategy ($s_{-i} = (0,0)$).

Changes in payoffs between Payoff Matrix A and Payoff Matrix B might alter players' calculations of the expected payoff differential in at least two ways. First, since Payoff Matrix A and Payoff Matrix B provide different payoffs in instances of partial coordination, the value of u_i when $s_i = 1$ and $s_{-i} \in \{(1,0),(0,1)\}$ will differ between treatments. Second, changing payoffs associated with partial coordination may also change the probabilities $\Pr(s_{-i})$ in the formula for expected payoff differential. As mentioned already, a given player may be more reluctant to play the payoff-dominant strategy under Payoff Matrix B than under Payoff Matrix A because under Payoff Matrix B the payoff-dominant strategy only yields a higher payoff than the secure equilibrium if $s_{-i} = (0, 0)$. Since the payoff matrices are symmetric, that reluctance may encourage the player to lower the probability with which she expects other players to play the payoff-dominant strategy as well.

It may also be reasonable to expect the number of times the game is repeated to affect play of the payoff-dominant strategy in the present treatments. In repeated games, players have the opportunity to shape the expectations of other players through the decisions early in the game. Players may venture selecting the payoff-dominant strategy in order to send a "signal" to other players and push the group toward the payoff-dominant equilibrium. In this way, players may be more willing to assume the risk of selecting the payoff-dominant strategy if they view it as an investment in future earnings later in the game. Furthermore, players may expect other players to signal as well. If players have an even stronger belief that other players will select the payoff-dominant strategy—in this case, as a result of the prospect of signaling—they, too, will play the payoff-dominant strategy, both in order to maximize payoffs in the first round and in subsequent rounds as well. In one-shot games, on the other hand, there is no opportunity to signal. First-round decisions in this case are informed only by players' private balancing of payoff dominance and security and their predictions regarding other players' balancing of payoff dominance and security. Thus, repeated games might be expected to magnify the salience of payoff dominance, relative to one-shot treatments.

These considerations can be summarized by the following conjectures. I conjecture that play of the payoff-dominant strategy will be greater in ONEA than ONEB (denoted ONEA > ONEB) and greater in REPA than REPB (REPA > REPB). I also conjecture that play of the payoff-dominant strategy in the first round to be greater in REPA than ONEA (REPA > ONEA) and greater in REPB than ONEB (REPB > ONEB).

2.2 Experimental procedures

Subjects were students at Indiana University who were recruited from a database of students majoring in a variety of disciplines. Subjects participated in the experiment in single groups of three but were recruited in groups of four or five, in case some subjects did not show up to sessions for which they registered. Upon arriving at the lab, subjects were seated randomly at computer monitors, where they read a set of instructions privately. The main points of these instructions were then reviewed aloud by the experimenter. Subjects were told that they would receive a cash amount based on their decisions and the decisions made by the other two members of their group. These cash amounts are described in the payoff matrices (see Table 1), which provide payoffs in cents. It was made clear during the instructions phase that all decisions would remain completely anonymous to other subjects. For repeated games, subjects were told they would receive a $5 "show-up" fee plus their earnings from the experiment in cents. For one-shot games, subjects were told that they would receive a $5 show-up fee plus their earnings in cents multiplied by 15. After the instructions phase, subjects took a quiz to confirm their understanding of the instructions for the experiment.[5]

Subjects submitted all decisions electronically via Microsoft OneNote software from their computer terminals. At the end of each round—in the case of repeated games—subjects received a feedback message on their computer screen that included a table with their decision for all previous rounds, the sum of other group members' decisions for all previous rounds, their payoff for all previous rounds and a running balance of their earnings for the experiment. Subjects were not informed of the individual decisions of the other two members of their group. At the conclusion of the experiment, subjects were allowed to exit one by one and given their cash earnings in private. Sessions employing repeated games lasted approximately one hour. One-shot sessions lasted approximately 30 minutes. Subjects earned between $15

[5] If there were wrong answers on quizzes, the instructions were reviewed again. However, this rarely occurred.

and \$35, and most subjects earned at least \$30.

3 Results

Over the course of four months, 16 experimental sessions were conducted, each with one group of three subjects. Sessions were divided evenly among the four treatments such that there were four sessions for each treatment, corresponding to a total of 12 observations for each decision round when pooling within treatments.[6]

Table 3 presents the frequency of play of the payoff-dominant strategy across treatments. (See Appendix A for the full dataset.) The most striking trend is the almost unanimous convergence to the payoff-dominant equilibrium. In repeated games, players selected the payoff-dominant strategy 91 percent of the time. Groups converged to the payoff-dominant equilibrium by the end of the sixth round in all but one session, and most groups reached the payoff-dominant equilibrium within two rounds. When subjects were asked to describe what motivated their decision-making in the experiment in a post-experiment questionnaire, the majority of subjects across all treatments said they assumed the two members of their group would recognize that the greatest payoff occurred when everyone selected the payoff-dominant equilibrium. While some subjects said they selected the secure strategy to "minimize risk," subjects in both repeated and one-shot games echoed the response given by one subject: "It was more of a risk picking 0 and missing out on the higher payoff." In line with Harsanyi and Selten (1988), subjects appear to have trusted one another, for the most part, to select the payoff-dominant strategy and, as a result, selected the payoff-dominant strategy themselves.

Table 3 also describes first-round play of the payoff-dominant strategy. Across both repeated game sessions, players selected the payoff-dominant strategy in the first round 88

[6]Two additional repeated game treatments, comprising an additional 8 sessions, were conducted with undergraduates at Indiana University. These treatments involved two payoff matrices which featured similar variation in payoffs associated with partial coordination but with greater differences in payoffs between strategies for each set of decisions by other group members. The results from those treatments are very similar to those from REPA and REPB.

percent of the time. That represents five instances where the group converged on the payoff-dominant equilibrium in the first round (and remained there for the duration of the game) and three instances where the group began out of equilibrium, with one player selecting the secure strategy and the other two selecting the payoff-dominant strategy. Of those three instances of out-of-equilibrium first-round decisions, one lead to a lack of coordination in subsequent rounds. In that case, the group collapsed to the secure equilibrium in rounds five and six, then spent the remaining rounds attempting to escape it and failing to settle on either equilibrium by the end of round 15.

Comparing first-round behavior in repeated games to one-shot games yields some evidence for the conjectures presented in the previous section. While first-round play of the payoff-dominant strategy in ONEA was statistically indistinguishable from first-round behavior in repeated games, ONEB saw a dramatic decline in the salience of the payoff-dominant strategy. In that treatment, players selected the payoff-dominant strategy just 58 percent of the time. Table 4 provides test statistics for the four conjectures presented earlier, using a two-tailed Fisher's exact test.[7] Fisher's test is significant at the 15-percent level of confidence for the conjecture that play of the payoff-dominant strategy is greater for one-shot games employing Payoff Matrix A than Payoff Matrix B.

While the statistical tests presented in Table 4 are insignificant at traditional confidence levels—due in part to limited sample size—the findings presented in this section provide at least some preliminary evidence that in one-shot games payoffs in instances of partial coordination influence the salience of payoff dominance. The simple rationale for this sort of behavior was articulated by one subject in ONEB: "I picked 0 because it offered a higher payout in the case that both of my group members did not also choose 1." Furthermore, the data suggest the effect of varying differences in payoffs associated with partial coordination is washed out by repeating the game. However, the most striking finding of all is the high frequency of play of the payoff-dominant strategy.

[7]Fisher's exact test is a modified Chi-squared test that is used with small sample sizes. For further discussion, see Agresti (1992).

4 Conclusion

Payoff dominance is highly salient for the set of coordination games examined in this paper, despite a large body of literature suggesting coordination on the Pareto-optimal equilibrium is uncommon when payoff-dominance and security are in conflict. Players appear to assign a high probability that other players will select the payoff-dominant strategy and, in order to maximize payoff, select the payoff-dominant strategy themselves. In responding to a question about the motivations for their decision-making, some subjects even suggested strategic selection in this type of coordination game is trivial. As one put it, "[...] if we select 1, everybody will maximize his or her profit. And everybody knows this point if they are smart enough to understand the instructions."

The experiments presented in this paper also provide some evidence that players in coordination games with multiple equilibria respond to changes in payoffs associated with partial coordination. The results suggest that in one-shot games players select the payoff-dominant strategy, which is associated with the Pareto-optimal equilibrium, less often when payoffs associated with partial coordination favor the alternative secure strategy than when payoffs associated with partial coordination do not favor either strategy. This result does not surface in repeated game protocols, following previous research suggesting payoff dominance is more salient when games are repeated.

References

Agresti, A. (1992). A survey of exact inference for contingency tables. *Statistical Science 7*, 131-177.

Andvig, J., and Moene, K. (1990). How corruption may corrupt. *Journal of Economic Behavior and Organization 13*, 63-76.

Berninghaus, S., and Ehrhart, K.-M. (1998). Time horizon and equilibrium selection in tacit coordination games: experimental results. *Journal of Economic Behavior and Organization 37*, 231-248.

Berninghaus, S., and Ehrhart, K.-M. (2002). Conventions and location interaction structures: experimental evidence. *Games and Economic Behavior 39*, 177-205.

Brandts, J., and Cooper, D. (2004). A change would do you good ... an experimental study on how to overcome coordination failure in organizations. *American Economic Review 69*, 669-693.

Brandts, J., and Cooper, D. (2006). Observability and overcoming coordination failure in organizations. *Experimental Economics 9*, 407-423.

Cachon, G., and Camerer, C. (1996). Loss-avoidance and forward induction in experimental coordination games. *Quarterly Journal of Economics 111*, 165-194.

Clark, K., Kay, S., and Sefton, M. (2001). When are Nash equilibria self-enforcing? an experimental analysis. *International Journal of Game Theory 29*, 495-515.

Clark, K., and Sefton, M. (2001). Repetition and signaling: experimental evidence from games with efficient equilibria. *Economics Letters 70*, 357-362.

Harsanyi, J., and Selten, R. (1988). A General Theory of Equilibrium Selection in Games (Cambridge: MIT Press).

Schmidt, D., Shupp, R., Walker, J., and Ostrom, E. (2003). Playing safe in coordination games: the roles of risk dominance, payoff dominance and history of play. *Games and Economic Behavior 42*, 281-299.

Van Huyck, J., Battalio, R., and Beil, R. (1990). Tacit coordination games, strategic uncertainty and coordination failure. *American Economic Review 80*, 234-248.

Van Huyck, J., Battalio, R., and Beil, R. (1991). Strategic uncertainty, equilibrium selection and coordination failure in average opinion games. *Quarterly Journal of Economics 106*, 885-910.

Von Neumann, J., and Morgenstern, O. (1972). Theory of Games and Economic Behavior (Princeton: Princeton University Press).

Table 1. Payoff matrices

PAYOFF MATRIX A

		Sum of other group members' decisions		
		0	1	2
Your decision	0	160	140	120
	1	80	140	200

PAYOFF MATRIX B

		Sum of other group members' decisions		
		0	1	2
Your decision	0	160	140	120
	1	80	80	200

Table 2. Description of treatments

Treatment	Payoff table	Repetition protocol	Number of players	Number of sessions
REPA	A	Repeated	3	4
REPB	B	Repeated	3	4
ONEA	A	One-shot	3	4
ONEB	B	One-shot	3	4

Table 3. Frequency of play of payoff-dominant strategy across treatments

	Treatment*			
Round	REPA	REPB	ONEA	ONEB
1	11	10	11	7
2	12	11		
3	12	10		
4	12	10		
5	12	9		
6	12	9		
7	12	10		
8	12	10		
9	12	10		
10	12	10		
11	12	10		
12	12	10		
13	12	11		
14	12	10		
15	12	10		
First-round average	91.7%	83.3%	91.7%	58.3%
Average across all rounds	99.4%	83.3%		

**Frequency taken out of 12 total decisions*

Table 4. Test statistics for conjectures

Conjecture	Two-tailed *p*-value for Fisher's exact test
ONEA > ONEB	0.15
REPA > REPB	1.00
REPA > ONEA	1.00
REPB > ONEB	0.37

APPENDIX A. Full dataset

REPA

Round	P1	P2	P3	Sum	Round	P1	P2	P3	Sum
1	1	1	1	3	1	1	1	1	3
2	1	1	1	3	2	1	1	1	3
3	1	1	1	3	3	1	1	1	3
4	1	1	1	3	4	1	1	1	3
5	1	1	1	3	5	1	1	1	3
6	1	1	1	3	6	1	1	1	3
7	1	1	1	3	7	1	1	1	3
8	1	1	1	3	8	1	1	1	3
9	1	1	1	3	9	1	1	1	3
10	1	1	1	3	10	1	1	1	3
11	1	1	1	3	11	1	1	1	3
12	1	1	1	3	12	1	1	1	3
13	1	1	1	3	13	1	1	1	3
14	1	1	1	3	14	1	1	1	3
15	1	1	1	3	15	1	1	1	3
1	1	1	1	3	1	1	0	1	2
2	1	1	1	3	2	1	1	1	3
3	1	1	1	3	3	1	1	1	3
4	1	1	1	3	4	1	1	1	3
5	1	1	1	3	5	1	1	1	3
6	1	1	1	3	6	1	1	1	3
7	1	1	1	3	7	1	1	1	3
8	1	1	1	3	8	1	1	1	3
9	1	1	1	3	9	1	1	1	3
10	1	1	1	3	10	1	1	1	3
11	1	1	1	3	11	1	1	1	3
12	1	1	1	3	12	1	1	1	3
13	1	1	1	3	13	1	1	1	3
14	1	1	1	3	14	1	1	1	3
15	1	1	1	3	15	1	1	1	3

REPB

Round	P1	P2	P3	Sum	Round	P1	P2	P3	Sum
1	0	1	1	2	1	1	1	1	3
2	1	0	1	2	2	1	1	1	3
3	0	1	0	1	3	1	1	1	3
4	0	1	0	1	4	1	1	1	3
5	0	0	0	0	5	1	1	1	3
6	0	0	0	0	6	1	1	1	3
7	0	1	0	1	7	1	1	1	3
8	1	0	0	1	8	1	1	1	3
9	0	1	0	1	9	1	1	1	3
10	1	0	0	1	10	1	1	1	3
11	1	0	0	1	11	1	1	1	3
12	1	0	0	1	12	1	1	1	3
13	1	1	0	2	13	1	1	1	3
14	1	0	0	1	14	1	1	1	3
15	1	0	0	1	15	1	1	1	3
1	1	1	1	3	1	0	1	1	2
2	1	1	1	3	2	1	1	1	3
3	1	1	1	3	3	1	1	1	3
4	1	1	1	3	4	1	1	1	3
5	1	1	1	3	5	1	1	1	3
6	1	1	1	3	6	1	1	1	3
7	1	1	1	3	7	1	1	1	3
8	1	1	1	3	8	1	1	1	3
9	1	1	1	3	9	1	1	1	3
10	1	1	1	3	10	1	1	1	3
11	1	1	1	3	11	1	1	1	3
12	1	1	1	3	12	1	1	1	3
13	1	1	1	3	13	1	1	1	3
14	1	1	1	3	14	1	1	1	3
15	1	1	1	3	15	1	1	1	3

ONEA

Round	P1	P2	P3	Sum
1	1	1	1	3
1	1	1	0	2
1	1	1	1	3
1	1	1	1	3

ONEB

Round	P1	P2	P3	Sum
1	0	0	1	1
1	1	1	1	3
1	0	1	0	1
1	1	1	0	2