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Mate Choice Mechanism for Solving a Quasi-Dilemma

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Abstract

Saijo, Okano, and Yamakawa (2014) showed that the mate choice mechanism for a symmetric prisoner's dilemma (*PD*) game implements cooperation in backward elimination of weakly dominated strategies (*BEWDS*), and it attained almost full cooperation in their experiment. First, this study shows that the mechanism works well in the class of quasi-dilemma (*QD*) games such as asymmetric *PD* games and coordination games. Second, the class of *BEWDS*-implementable games is exactly the same as the class of *QD* games. Third, the mechanism cannot implement cooperation in a subgame perfect equilibrium. Finally, we confirm that the mate choice mechanism works well experimentally for an asymmetric *PD* game.

1. Introduction

This study is part of our endeavor to find one of the *simplest* possible mechanisms to solve social dilemmas, including the prisoner's dilemma (*PD*), public good provision, and coordination, both experimentally and theoretically.[1] Experimentally, we aim to design mechanisms that can attain a Pareto efficient outcome in a few rounds,[2] because we cannot repeat the same mechanism many times in real-life settings. Theoretically, we seek *natural* behaviors among subjects in experiments rather than stick to Nash or Nash-type equilibrium

[1] See, for example, Huang, Masuda, and Saijo (2014), Masuda, Okano, and Saijo (2014), and Saijo, Okano, and Yamakawa (2014). Masuda et al. (2014) constructed a mechanism that implements a Pareto efficient allocation in a public good economy when the number of players is two and their preferences are linear, and then, they conducted experiments in which the rate of contribution is 94.9%. The mechanism, called the minimum approval mechanism, is a version of the mate choice mechanism. Huang et al. (2014) constructed a mechanism that implements cooperation when the number of players is at least two. They conducted experiments in which the rate of cooperation is more than 90% after period 4 with three players. The mechanism is called the simplified approval mechanism, and it is also based upon the mate choice mechanism.

[2] Chen (2005), for example, found that the stability property of mechanisms depends on their supermodularity. Supermodular mechanisms may require many periods to converge to a desired outcome. The goal of the endeavor is not to find such mechanisms but to find mechanisms that can attain a desired outcome in a few periods.

concepts. In addition, we do not use punishment or reward to balance the budget in the mechanism design.[3]

The study by Saijo, Okano, and Yamakawa (2014) is one of the first attempts to design such a mechanism for the *PD*. They proposed the mate choice mechanism after a *symmetric PD* game. After observing the choice of cooperation (*C*) or defection (*D*) in the *PD* game, each player approves or disapproves the other's choice: if both approve it, the outcome is what they chose in the *PD* game, and if at least one player disapproves the other choice, the outcome is that when both defect, which is called the mate choice (*MC*) mechanism. Because the *MC* mechanism does not have devices such as punishment or reward, it is budget balanced.

Experimentally, they observed that the cooperation rate, that is, the ratio of subjects who chose cooperation, with the mechanism was 95.0% in round 1 and 96.9% through 19 rounds, when each subject was never matched with the same subject again in all rounds.[4] The (*C,C*) share, that is, the ratio of pairs in which both chose C, was 90.0% in round 1 and 94.0% through 19 rounds. They also found that subjects' behavior was consistent with backward elimination of weakly dominated strategies (*BEWDS*) rather than Nash equilibrium (*NE*) or subgame perfect equilibrium (*SPE*) behavior. *BEWDS* is a procedure to eliminate weakly dominated strategies in each subgame backwardly. We also call the strategies that survive through the procedure *BEWDS* strategies. Theoretically, the *MC* mechanism implements cooperation in *BEWDS* for symmetric *PD* games.[5]

Our paper expands the domain of this mechanism from symmetric *PD* games to *asymmetric* games that are not necessarily *PD* games. We find that the *MC* mechanism implements cooperation in *BEWDS* for the class of *quasi-dilemma* (*QD*) games, which contains coordination games, including the stag hunt game and *PD* games. Furthermore, under several mild conditions, we show that the class of games implementing cooperation in *BEWDS* is exactly the same as the class of *QD* games. On the other hand, the *MC* mechanism cannot implement cooperation in *SPE*.

In order to test the performance of the *MC* mechanism in an asymmetric environment,

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[3] According to Guala (2013), *strong reciprocity*, in which a player punishes other players using the player's own resource, is rare in human history.

[4] This is called complete stranger matching, and only a few experiments employ this matching. Saijo et al. (2014) chose this matching since it is the least favorable design for cooperation with respect to matching.

[5] The *MC* mechanism uses unanimity. Banks, Plott, and Porter (1988) introduced a voting stage after a public good provision stage and observed that unanimity reduced efficiency. Researchers stopped pursuing this avenue after Banks et al. (1988) presented their findings. Furthermore, Masuda et al. (2014) found that the *MC* mechanism cannot implement a Pareto-efficient allocation in *BEWDS* for an economy with a public good.

we choose an asymmetric *PD* game in which cooperation cannot be attained by the compensation mechanism in *SPE* that is proposed by Charness, Fréchette, and Qin (2007). The compensation mechanism asks players to transfer money to the other player in the first stage, and then, they both play a *PD* game. The monetary transfer must be done when the other player chooses cooperation in the *PD* stage. The compensation mechanism does not cover all *PD* games although the mate choice mechanism covers all *PD* games, and moreover, it covers non-*PD* games. That is, there is a class of *PD* games in which the compensation mechanism cannot implement cooperation in *SPE*.

Experimentally, we observed that the cooperation rate with the mechanism is 76.7% in round 1, 86.7% in round 2, 93.3% in round 3, and 96.7% through 19 rounds. The (*C*,*C*) share is 56.7% in round 1, 73.3% in round 2, 86.7% in round 3, and 93.5% through 19 rounds. That is, the *MC* mechanism works reasonably well although it took a few rounds to achieve high (*C*,*C*) shares in an asymmetric *PD* game with the *MC* mechanism.

Section 2 describes the *MC* mechanism applied to *QD* games. Section 3 proves that *BEWDS* implementable games are *QD* games and shows that the *MC* mechanism cannot implement cooperation in *SPE*. Section 4 presents the experimental design, and section 5, the results. Section 6 provides suggestions for further research.

2. The mate choice mechanism and quasi-dilemma games

Consider a 2 x 2 game that has two strategies: cooperation (*C*) and defection (*D*).

	C	*D*
C	$(a,v)=V$	$(b,w)=W$
D	$(c,x)=X$	$(d,z)=Z$

Figure 1. A *QD* game.

Define function p as follows: $p(C,C) = (a,v) = V$, $p(D,C) = (c,x) = X$, $p(C,D) = (b,w) = W$, and $p(D,D) = (d,z) = Z$. If p satisfies $V > Z$ ($a > d$ and $v > z$), $X \ngeq Z$ ($d > c$ or $z > x$), and $W \ngeq Z$ ($d > b$ or $z > w$), then p is a *QD game*, and if p satisfies $V > Z$, $(c,d) > (a,b)$ and $(w,z) > (v,x)$, then p is a *PD game*.[6] Coordination games, including the stag hunt game, are *QD* games.

[6] ">" shows that each element of the left-hand-side vector is "strictly greater than" each element of the right-hand-side vector, and "≥" shows that each element of the left-hand-side vector is "greater than or equal to" each element of the right-hand-side vector.

Property 1. *A prisoner's dilemma game is a quasi-dilemma game.*

Proof. Let p be a *PD* game. Suppose that $(a,v) > (d,z)$, $(c,d) > (a,b)$, and $(w,z) > (v,x)$. Given $V = (a,v)$ and $Z = (d,z)$, let $X = (c,x)$ and $W = (b,w)$ satisfy the conditions. Then, $c > a$, $z > x$, $d > b$, and $w > v$. This implies that $z > x$ and $d > b$, showing that ($d > c$ or $z > x$) and ($d > b$ or $z > w$). That is, $X \ngtrsim Z$ and $W \ngtrsim Z$. ∎

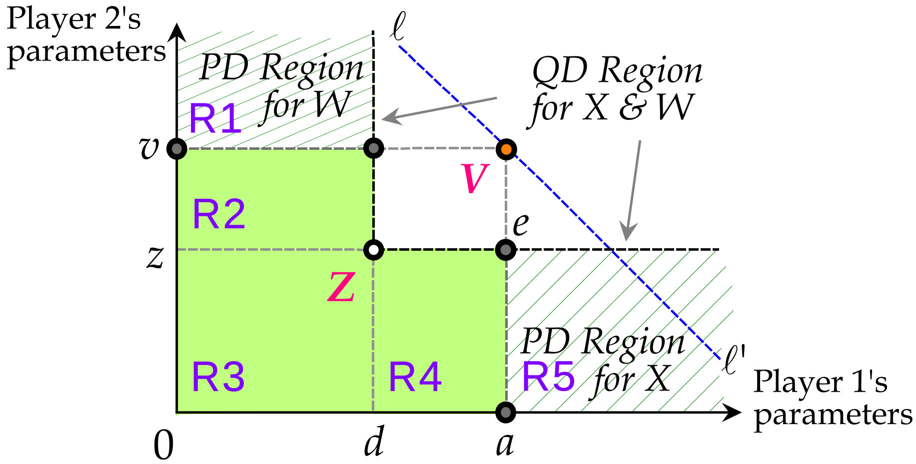

Figure 2. Possible locations of X and W in *QD* and *PD* games.

Figure 2 shows the possible locations of X and W in *QD* and *PD* games. The region for *QD* games is the dark *L*-shaped area (i.e., R1, R2, R3, R4, and R5), and the regions for *PD* games are R1 for W and R5 for X. Line $\ell - \ell'$ shows that the sum of benefits of both players is equal to $a + v$. If V must be Pareto efficient, X and W must be located under $\ell - \ell'$. We do not impose this condition hereafter.

Let us define the *MC* mechanism. Players first choose either C or D in Figure 1. After this stage, each subject can approve (y) or disapprove (n), the other player's choice in the second stage. If both approve the other player's choice, the outcome is what they choose, and if either one disapproves the other player's choice, the outcome is that both defect. Let M_i, m_i, and u_i be player i's choice between C and D, i's choice between y and n, and i's payoff, respectively. Then, the *MC* mechanism is defined by the following rule: if $m_1 = m_2 = y$, then $(u_1, u_2) = p(M_1, M_2)$; otherwise, $(u_1, u_2) = p(D, D)$. In general, we call the two-stage game without rule specification an *approval* mechanism.

Saijo et al. (2014) prepared five possible behavioral principles in their experiments for the *MC* mechanism: the *NE*, the *SPE*, evolutionarily stable strategies (*ESS*), neutrally stable strategies (*NSS*), and *BEWDS*. Of the five behavioral principles, the data of their experiments are most compatible with *BEWDS*.

Since we focus upon *SPE* and *BEWDS*, let us define them. As we show later, since there is no need to consider mixed strategies in our framework, a profile of strategies indicates an assignment of a pure strategy for each information set. A profile of strategies is a *SPE* if the restriction of the profile at each subgame is a Nash equilibrium. Let us fix a subgame, and we say that a strategy at an information set in the game *survives the elimination of weakly dominated strategies* if the strategy is not weakly dominated by any other strategies in the set.[7] A profile of strategies is a *BEWDS* if the restriction of the profile at each subgame survives the elimination of weakly dominated strategies. A mechanism *implements* cooperation in *SPE* (or *BEWDS*) if all players choose cooperation in the first stage under *SPE* (or *BEWDS*). Next, we show that the *MC* mechanism with a *QD* game implements cooperation under *BEWDS*.

Property 2. *The mate choice mechanism with a QD game implements the cooperative outcome under BEWDS.*

Proof and Interpretation. The *MC* mechanism with a *QD game* has four subgames in Figure 3. Because of the definition of the *MC* mechanism, we have $(u_1, u_2) = (d, z)$ at (*y,n*), (*n,y*), and (*n,n*) for each subgame. This was termed the *MC flat* by Saijo et al. (2014), because the three cells other than (*y,y*) have the same payoff vector.

Consider subgame *CC* where both choose *C*. Player 1 must compare (*a,d*) and (*d,d*). Because $a > d$, player 1 chooses *y* based upon the elimination of weakly dominated strategies. However, player 1 does not necessarily compare two vectors because of the *MC* flat. Player 1 should compare *a* and *d* to understand this domination.

Although player 1 can choose either *y* or *n* based only on the elimination of weakly dominated strategies, player 1 must also consider player 2's choice. Player 1 compares *v* and *z*, and hence, player 1 understands that player 2 chooses *y*. Thus, player 1 understands that the choice at (*C,C*) is (*y,y*), which is shown by the bold square in Figure 3 for subgame *CC*. Therefore, player 1 can fill the (*C,C*) part of the reduced normal form game with (*a,v*), which is

[7] Let *X* and *Y* be strategies of a player, and let (*a,b*) and (*c,d*) be payoff vectors when the player chooses *X* and *Y*, respectively. *X weakly dominates Y* if and only if $a \geq c,\ b \geq d$, and there is at least one strict inequality. Notice that no strategies could survive if we use strong domination with strict inequality of each element.

located above the four subgames in Figure 3.

Consider subgame *DC*. Because $X \not\geq Z$, $d > c$ or $z > x$. Suppose that $z > x$. Then, player 2 chooses n and understands that the outcome is (d,z) regardless of the choice of player 1 in this subgame. However, as a thought experiment, player 1 must consider player 2's choice if it were $c > d$. That is, although player 1 would choose y, player 1 could not identify which of (c,x) and (d,z) would be realized without knowing player 2's choice. Suppose $d > c$. Player 1 chooses n and understands that the outcome is (d,z) without considering player 2's choice.

Repeating the same procedure at each of the subgames *CD* and *DD*, player 1 can construct the reduced normal form game above the four subgames in Figure 3. Because the game also has the *MC* flat and $a > d$, player 1 chooses *C*.

If player 1 understands that player 2's position is the same as that of player 1 using the same procedure, player 1 is convinced that player 2 also chooses (C,y). If so, the equilibrium path under *BEWDS* is $((C,C),(y,y))$. Thus, we simply write (C,C,y,y) hereafter. ■

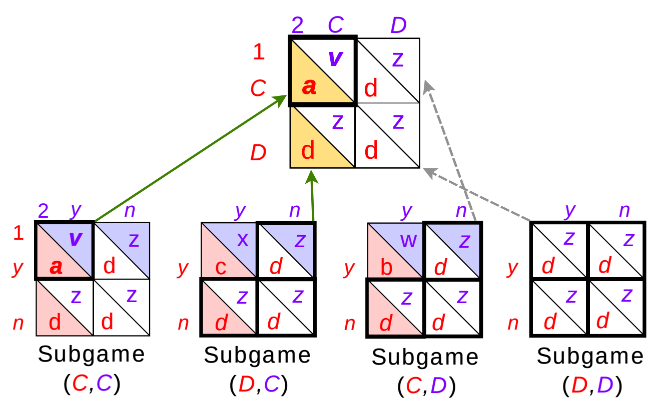

Figure 3. Construction of the reduced normal form game.

Although this proof is mathematically almost the same as that of Saijo et al. (2014), there are several differences between the two because of possible asymmetry. First, because they used the symmetric payoff table, $d = z$, all components of the three cells have the same number. In this sense, these three cells have the *completely* flat property. Therefore, the change from $d = z$ to $d \neq z$ might increase the player's burden to understand the game. Second, (a,d) is different from (v,z), although $(a,d) = (v,z)$ in Saijo et al. (2014). This change also increases the players' burden. The same argument can be applied to all subgames. Third, players who understand the strategic implication of vectors *V*, *W*, *X*, and *Z* in the symmetric case might not be able to understand it in the asymmetric case under *BEWDS*. Finally, even though players may understand these points, the difference between a and v may evoke an "equity" module in their brains, which could trigger "non-rational" motivation.

An important property of the *MC* mechanism is that it is *onto*: the set of possible outcomes of a *QD* game is equal to those of the *MC* mechanism. The former is $\{V,W,X,Z\}$, and the latter must be the same. For example, although player 1 does not want to choose y at (C,D), W is the outcome if both choose y. This condition excludes any payoff flow from or to the game. In other words, no outside penalty or reward is given in order to maintain a balanced budget.[8]

3. Backward elimination of weakly dominated strategies implementable games are quasi-dilemma games

We consider the tightness of the parameter space of *QD game*s and the implementable parameter space of *BEWDS*. If the latter is larger, the idea of *BEWDS* implementation can be applied to many other 2 x 2 games. However, we show that these two spaces are identical under several assumptions.[9]

First, the approval mechanism satisfies *forthrightness*: If both choose y in the second stage after the choice of a strategy pair in the first stage, the outcome must be that strategy pair.[10] That is, the outcome must be what they choose whenever both choose y. Second, the approval mechanism has a *flat*: the outcome of the second stage, except for (y,y), and that of the reduced game, except for (C,C), are the same. Thus, we have the following property.

Property 3. *Suppose that $V > Z$ and that an approval mechanism satisfies forthrightness with the flat, Z. Then, the class of games implementing cooperation in BEWDS is exactly the same as that of QD games.*

Proof. Consider any approval mechanism implementing outcome V in *BEWDS.* Because forthrightness is satisfied, if both choose y, the outcomes of subgames *CC*, *CD*, *DC,* and *DD* must be V, W, X, and Z, respectively. Because Z is the flat and the mechanism implements

[8] The money-back-guarantee mechanism introduced by Dawes, Orbell, Simmons, and van de Kragt (1986) and Isaac, Schmidtz, and Walker (1989) is not *onto*. Let C be a fixed amount of contribution for public good provision, and let D be no contribution. The money-back-guarantee mechanism returns the contribution to a player if both do not contribute, and hence, X and W cannot be the outcomes of the mechanism. If player 1 is a utilitarian, and hence prefers X to Z, the *MC* mechanism can choose X unlike the money-back-guarantee mechanism.

[9] These assumptions are essentially the same as those introduced by Saijo et al. (2014).

[10] Saijo, Tatamitani, and Yamato (1996) introduced forthrightness in the natural mechanism design.

cooperation, the outcome should be Z in subgames *CD* and *DC*. That is, ($d > b$ or $z > w$) and ($d > c$ or $z > x$) for subgames *CD* and *DC*, respectively. Because $\overline{(d > b \text{ or } z > w)} =$ $(d \le b \text{ and } z \le w) = (W \ge Z)$, ($d > b$ or $z > w$) is equivalent to $W \not\ge Z$. Similarly, we obtain $X \not\ge Z$. That is, the class of games implementing cooperation in *BEWDS* is exactly the same as the class of *QD* games. ∎

Let us now consider the *SPE*s of *QD* games. Since the Nash equilibrium outcomes are (a,v) and (d,z) at subgame *CC* and (d,z) at subgames *DC, CD*, and *DD*, two cases exist in the reduced normal form games shown in Figure 4. That is, because all combinations, (*C,C*), (*D,C*), (*C,D*), and (*D,D*), are Nash equilibria of the games, they are also the outcomes of *SPE*s. Therefore, the *MC* mechanism cannot implement cooperation in *SPE*.

(i) (y,y) in subgame *CC*

Player 1 \ Player 2	*C*	*D*
C	***a,v***	*d,z*
D	*d,z*	***d,z***

(ii) (n,n) in subgame *CC*

Player 1 \ Player 2	*C*	*D*
C	***d,z***	***d,z***
D	***d,z***	***d,z***

Bold italic cells indicate Nash Equilibria in the reduced normal form games.

Figure 4. Two reduced normal form games.

As the above discussion shows, multiple Nash equilibria in a subgame generate multiple *SPE*s due to the *MC* flat. Furthermore, players in *SPE* must consider how the other player behaves in each subgame. In this sense, *SPE* might place a heavy information burden on players. On the other hand, players in *BEWDS* do not need information about how the other player behaves since they care about the comparison of their own strategies in each subgame as far as the *BEWDS* strategy is unique. However, this fact does not necessarily support *BEWDS* in general since the facts are specific to the *MC* mechanism. The next two sections describe the experiment and its results.

4. Experimental design

Our experimental focus is payoff asymmetry of the *PD* game. We conducted experiments of an asymmetric *PD* game with the *MC* mechanism (*AsymPDMC*). For comparison with the data of the *AsymPDMC*, we borrowed the data regarding a symmetric *PD* game with the *MC* mechanism (*SymPDMC*) and a symmetric *PD* game without the *MC* mechanism (*SymPD*) from Saijo et al. (2014).

We chose an asymmetric payoff table in which cooperation cannot be implemented by the compensation mechanism in *SPE*, but it can be implemented by the *MC* mechanism in *BEWDS*. The compensation mechanism also has two stages. It asks players to transfer money to the other player in the first stage, and then, both play a *PD* game. The monetary transfer must be done when the other player chooses cooperation in the *PD* stage. Varian (1994) designed the compensation mechanism in a general setting, and then, Andreoni and Varian (1999) and Charness et al. (2007) conducted the experiments using the *PD* games. As Charness et al. (2007) showed, the compensation mechanism does not cover the entire class of *PD* games. In this sense, we chose one of the least favorable matrices to achieve cooperation in our experimental design. Figure 5 shows the symmetric and asymmetric payoff matrices.[11] The symmetric payoff table comes from Saijo et al. (2014) and the asymmetric payoff matrix comes from Charness et al. (2007). The average cooperation rates in Charness et al. (2007) are 43-68% with the compensation mechanism.

		Player 2	
		C	*D*
Player 1	*C*	14,14	7,17
	D	17,7	10,10

(i) Symmetric payoff matrix

		Player 2	
		C	*D*
Player 1	*C*	44,36	8,44
	D	52,0	32,28

(ii) Asymmetric payoff matrix

Figure 5. Symmetric and asymmetric payoff matrices.

All the above-mentioned experiments were carried out in Osaka University during the period from November 2009 to December 2011. The *AsymPDMC* and *SymPDMC* experiments each had three sessions, and the *SymPD* experiment had one session. Twenty subjects participated in each session and no subject attended more than one session. We recruited these 140 undergraduate subjects with different majors through campus-wide advertisements. They were told that there would be an opportunity to earn money in a research experiment.

At the beginning of the experiment, each subject had a set of printed instructions and a record sheet. Instructions were read aloud by an experimenter. After that, subjects were

[11] In the experiment, we used payoff numbers that are 100 times the numbers in Figure 5 due to the exchange rate.

given five minutes to ask private questions. Communication among subjects was prohibited, and we declared that the experiment would be stopped if it was observed. This never happened. There was no practice period. We used the z-Tree software (Fischbacher, 2007) for the experiment.

The experimental procedure was as follows. We formulated 10 pairs out of the 20 subjects seated at computer terminals in each session. These pairings were anonymous and determined in advance in order not to pair the same two subjects more than once. Since most previous studies, such as Andreoni and Varian (1999) and Charness et al. (2007), have employed random matching among four to eight subjects (two to four groups),[12] such repetition necessarily entails pairings of the same two subjects. Therefore, compared with previous experiments, this "complete" strangers design might reduce the possibility of cooperation among subjects.[13] Each subject received an instruction sheet and a record sheet.

Let us explain the *PDMC* experiment. When the period started, each subject selected either *A* (defection) or *B* (cooperation) in the choice (or *PD*) stage and then inputted the choice into a computer and also noted it on the record sheet. After that, each subject explained the reason behind this choice in a small box on the record sheet. The next step was the decision (or approval) stage. Based on the knowledge of the other subject's choice, each subject chose to either "accept" or "reject" it and then inputted the decision into a computer, noted it on the record sheet, and explained his or her reasoning as before. Once subjects had finished the task, each could see "your decision," "the other's decision," "your choice," "the other's choice," "your points," and "the other's points" on the computer screen. However, neither the choices nor the decisions in pairs other than "your" own were shown on the computer screen. This ended one period. The experiment without the approval stage became the *PD* experiment. After finishing all 19 periods, every subject filled in questionnaire sheets.

Each session lasted approximately 90 minutes including the time spent on answering the post-experiment questionnaires and payment. Subjects earned, on average, 5233 JPY (about 43.61 USD, using 1 USD=120JPY), 4873 JPY (about 40.61 USD), and 3920 JPY (about 32.67USD) in *AsymPDMC*, *SymPDMC*, and *SymPD* sessions, respectively.

5. Experimental results

Figure 6 shows the time path of cooperation rates over the 19 periods. The

[12] Charness et al. (2007) divided 16 subjects in one session into four separate groups, with four subjects in each group interacting only with each other over the course of the session.

[13] An exception is Cooper, DeJong, Forsythe, and Ross (1996), who employed complete stranger matching.

cooperation rate in each period is defined as the ratio of number of subjects choosing *C* to the total number of subjects. As shown, the cooperation rate of *PD* started at 15% in the first three periods, and then ranged between 5% and 10% in the next 16 periods. In contrast, the cooperation rate of *SymPDMC* was always above 90% in each period, while that of *AsymPDMC* started at about 76.7% in the first period, rose to 86.7% in the second period, and then stayed above 90% in the remaining 17 periods.

The large gap in cooperation rates between *PD* and *PDMC* (either symmetric or asymmetric) was statistically supported by the proportion test. All the *p* values for comparing the cooperation rate of *AsymPDMC* or *SymPDMC* with that of *PD* are smaller than 0.001 in each period, which suggests that introducing the second stage after the *PD* game dramatically increases the cooperation rate in both symmetric and asymmetric *PD* games.

For the comparison of *AsymPDMC* with *SymPDMC*, we ran the proportion test by using both the data of each period and the data pooled over all periods. The two-tailed *p* values are reported in Table 1 (see the fourth column from the left). Generally, there is no significant difference in the cooperation rates between an asymmetric *PD* and a symmetric *PD* games when the data were pooled over all periods ($p = 0.7212$). In the first two periods, the cooperation rate is significantly lower under the asymmetric environment. Thereafter, the cooperation rate in the asymmetric mate choice mechanism no longer remains *statistically significantly* lower than its symmetric counterpart. In fact, a significantly higher cooperation rate in *AsymPDMC* is even observed in 3 periods (i.e., periods 7, 14, and 15) out of the remaining 17 periods.

With regard to the share of the (*C,C*) combination, Figure 7 shows its time path over the 19 periods. Applying the proportion test, we found that the (*C,C*) share is significantly higher in either *AsymPDMC* or *SymPDMC* than in *PD* in each period (all p values < 0.001). Additionally, as indicated in the last column of Table 1, there is no significant difference in the share of the (*C,C*) combination between *AsymPDMC* and *SymPDMC* ($p = 0.6031$) when the data were pooled over all periods. However, if we look at the *p* values by period, we find that the (*C,C*) share is significantly lower in the asymmetric environment than in the symmetric environment in the first four periods. Thereafter, similar to the case of the cooperation rate, the share of *AsymPDMC* is once again always statistically higher than or equal to its symmetric counterpart.

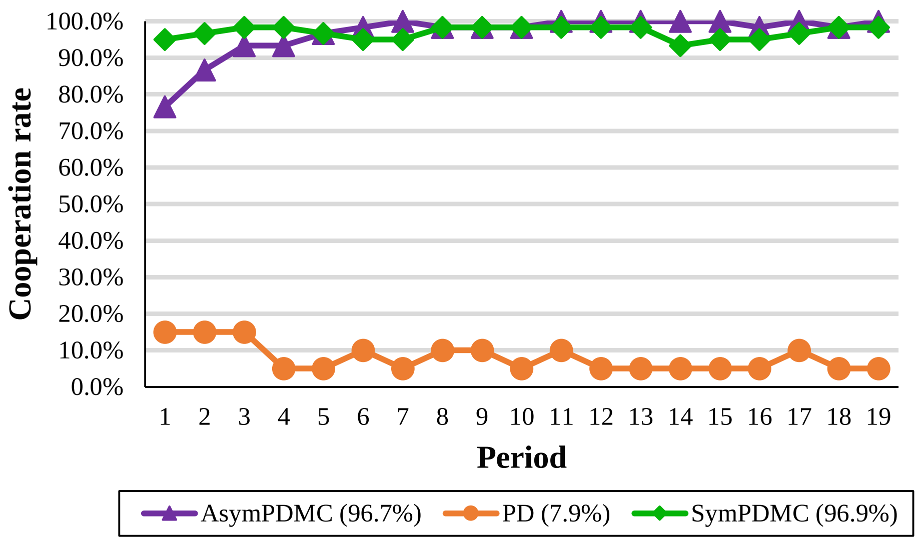

Figure 6. Cooperation rates by periods.

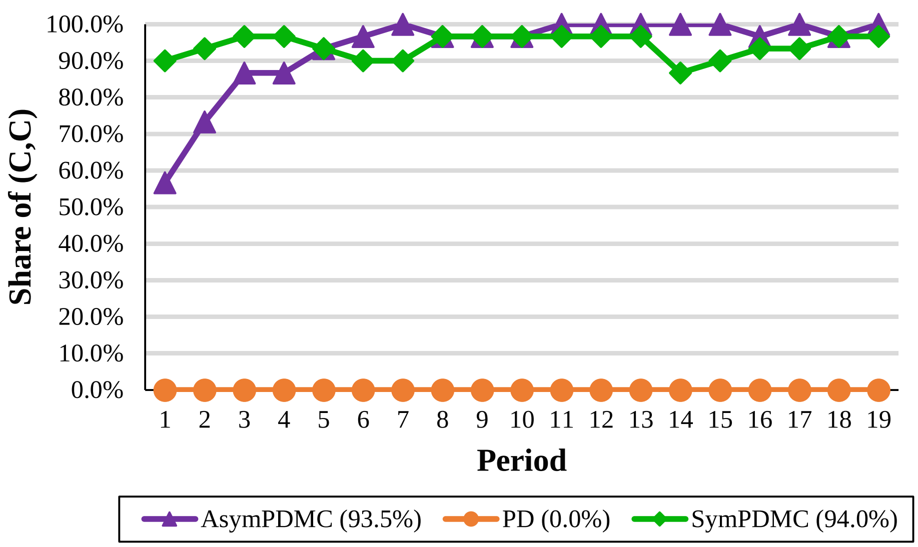

Figure 7. Share of (*C*,*C*) by periods.

Table 1. Proportion test results for *AsymPDMC* vs. *SymPDMC*.

Period	Cooperation rate			Share of (*C*,*C*)		
	AsymPDMC	*SymPDMC*	*p* value	*AsymPDMC*	*SymPDMC*	*p* value
1	76.7%	95.0%	0.0040	56.7%	90.0%	0.0000
2	86.7%	96.7%	0.0475	73.3%	93.3%	0.0033
3	93.3%	98.3%	0.1705	86.7%	96.7%	0.0475
4	93.3%	98.3%	0.1705	86.7%	96.7%	0.0475
5	96.7%	96.7%	1.0000	93.3%	93.3%	1.0000
6	98.3%	95.0%	0.3091	96.7%	90.0%	0.1432
7	100.0%	95.0%	0.0794	100.0%	90.0%	0.0120
8	98.3%	98.3%	1.0000	96.7%	96.7%	1.0000
9	98.3%	98.3%	1.0000	96.7%	96.7%	1.0000
10	98.3%	98.3%	1.0000	96.7%	96.7%	1.0000
11	100.0%	98.3%	0.3153	100.0%	96.7%	0.1538
12	100.0%	98.3%	0.3153	100.0%	96.7%	0.1538
13	100.0%	98.3%	0.3153	100.0%	96.7%	0.1538
14	100.0%	93.3%	0.0419	100.0%	86.7%	0.0034
15	100.0%	95.0%	0.0794	100.0%	90.0%	0.0120
16	98.3%	95.0%	0.3091	96.7%	93.3%	0.4022
17	100.0%	96.7%	0.1538	100.0%	93.3%	0.0419
18	98.3%	98.3%	1.0000	96.7%	96.7%	1.0000
19	100.0%	98.3%	0.3153	100.0%	96.7%	0.1538
All periods	96.7%	96.9%	0.7212	93.5%	94.0%	0.6031

Notes: The reported *p* values are based on the two-tailed proportion test.

6. Concluding remarks

We showed that the *MC* mechanism implements cooperation in *BEWDS* for *QD* games and that *BEWDS*-implementable games are *QD* games. *QD* games include not only *PD* games but also coordination games. Furthermore, the mechanism cannot implement cooperation in *SPE*.

The *MC* mechanism is essentially a unanimous voting rule between two players, and it can be interpreted as a "minimum" communication device to achieve cooperation. In the first stage, each player reveals the choice of *C* or *D*. Then knowing the other's choice, each chooses *y* or *n*. If both choose *y*, the outcome is what they choose in the first stage; otherwise, the outcome is (*D,D*). This mechanism implicitly presupposes that the status quo is (*D,D*) and disagreement results in the status quo. This procedure can be a *natural* way to avoid conflict, such as *PD,* or a coordination situation in daily life. Using functional near-infrared spectroscopy (*fNIRS*), Nagatsuka, Shinagawa, Okano, Kitamura, and Saijo (2013) found that compared with the *PD* game, subjects made their choices with less stress using only the *MC* mechanism. We also found that except for first few periods, the *MC* mechanism works well under an asymmetric environment.

Masuda, Okano, and Saijo (2014) expanded the idea of the *MC* mechanism to public good provision and showed that the minimum approval mechanism implements an efficient allocation in *BEWDS* theoretically and experimentally. Furthermore, Huang, Masuda, Okano, and Saijo (2014) designed a simplified approval mechanism in the spirit of the *MC* mechanism in a social dilemma and showed theoretically and experimentally that it implements cooperation in *BEWDS* when there are at least two players. However, designing a reasonable approval mechanism to implement cooperation in multiple choices and players is an open question.

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