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Approval Mechanism to Solve Prisoner's Dilemma:
Comparison with Varian's Compensation Mechanism

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Abstract

After having played a prisoner's dilemma, players can approve or reject the other's choice of cooperation or defection. If both players approve the other's choice, the outcome is the result of the chosen strategies in the prisoner's dilemma; however, if either rejects the other's choice, the outcome is the same as if they had mutually defected from the prisoner's dilemma. In theory, such an approval mechanism implements cooperation in backward elimination of weakly dominated strategies, although this is not the case in the subgame perfect Nash equilibrium. By contrast, the compensation mechanism proposed by Varian (1994) implements cooperation in the latter but not in the former. This result motivates the present experimental study of the two mechanisms. The approval mechanism sessions yield a cooperation rate of 90% in the first period and 93.2% across periods, while the compensation mechanism sessions yield a cooperation rate of 63.3% in the first period and 75.2% across periods. In addition, the backward elimination of weakly dominated strategies better predicts subjects' behavior than does the subgame perfect Nash equilibrium in both mechanism sessions.

JEL codes: C72, C73, C92, D74, P43

Keywords: prisoner's dilemma, approval mechanism, cooperation, backward elimination, weakly dominated strategies, laboratory experiment, Selten's index

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1. Introduction

To achieve efficient public goods provision, it is necessary to align participants' individual interests with their collective interests. Although mechanisms have been developed in such a way in a general setting, the observed outcomes often deviate from the desired ones in laboratory experiments mirroring such a setting (Chen, 2008). In order to better understand the combination of mechanisms and behavioral theory that works well with human subjects, it is helpful to employ the simplest possible experimental setting.

Subgame perfect Nash equilibrium (SPNE) is an example of a behavioral assumption that has been challenged in social dilemma experiments. Varian (1994) proposed a mechanism to attain efficiency in SPNE, calling it a compensation mechanism (CM). The mechanism gives players an opportunity to offer transfers contingent on cooperative action prior to playing the underlying game. Applying the CM to the prisoner's dilemma (PD), at equilibrium, players mutually cooperate after having offered to compensate each other with the gain from unilateral defection.[1] Despite the theoretical properties of the CM, experimental evidence appears to contradict theory. In the PD with Andreoni and Varian's (1999) CM experiment, about one-third of the subjects faced difficulties in achieving SPNE even after having repeated the game 20 times. More recent studies have reported substantial deviations from SPNE in CM experiments with more complex externality settings.[2] Thus, designing multi-stage mechanisms that work well in the laboratory remains a challenging problem.

In this study, we attempt to address this challenge by introducing the *approval mechanism* (AM). Consider adding an approval stage after the PD, where each subject can approve ("*yes*") or disapprove ("*no*") the other's choice of strategy in the first stage. If both approve the other's strategy, the outcome is the result of the chosen strategies in the PD; however, if either disapproves, the outcome is the same as if they had mutually defected from the PD.[3] The *AM* implements cooperation in *backward elimination of weakly dominated strategies* (BEWDS) but not in SPNE (Properties 1 and 2). By contrast, the CM implements cooperation in SPNE but not in BEWDS (Property 3). These contrasting features of the AM and CM motivate us to compare them experimentally.

The experimental data suggest that the AM works better than the CM. We employ a between-subject and complete-stranger design. The AM sessions yield a cooperation rate of 90% in the first period and 93.2% across periods, whereas the CM sessions yield a rate of 63.3% in the

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1 This holds provided the payoff asymmetry in the underlying prisoner's dilemma is not too large (Qin 2005).

2 See Hamaguchi et al. (2003), Bracht et al. (2008), and Midler et al. (2015). For Moore-Repullo SPNE mechanism experiments, see Fehr et al. (2014).

3 Selten (1975) and Kalai (1981) applied BEWDS to game theory.

first period and 75.2% across periods, showing a statistically significant difference in the mean cooperation rate between the AM and CM.

A classification of group-level data reveals that BEWDS is a better predictor of subjects' behavior in both the AM and CM. Under the AM, the BEWDS path is unique (Property 1), but there are multiple SPNE paths (Property 2). Moreover, SPNE paths include a BEWDS path. However, the opposite holds for the CM (Property 3). These properties motivate us to use Selten's index of predictive success (Selten 1991), which captures both the correctness and parsimony of equilibrium predictions. The data for the AM show that Selten's index for BEWDS is about double that of SPNE, suggesting that BEWDS is a better predictor. On the other hand, the data for the CM show that, although BEWDS yields a slightly higher Selten's index than SPNE does, neither equilibrium concept fits the data well.

The contributions of this study to the mechanism experiment literature are threefold. First, we successfully design a two-stage mechanism that works better than the CM in laboratory experiments. The result could be attributed to the simplicity of backward thinking under the AM. In other words, the AM subjects have to check only four second stages, while the CM subjects have a large number of transfer options, and hence face a heavy cognitive burden to think backwardly, which hinders efficiency, as reported by Midler et al. (2015). Moreover, a noteworthy feature of the AM is that it does not utilize private punishment and/or reward technologies, which are sometimes assumed in the literature (Varian 1994; Fehr and Gächter 2000). However, since personal punishment (or bribe) is generally prohibited in modern societies and legal systems, we view this as a strength of the AM.[4] On the other hand, under the AM, when either player disapproves of the other's choice, the public good will not be provided, and thus, the money is simply returned to the contributor. Second, our experimental design with symmetric PD removes equity concerns regarding final payoffs, since, as Charness et al. (2007) pointed out in their CM experiment with asymmetric PDs, asymmetric PDs might hinder the achievement of SPNE. Third, our analysis of group-level data sheds light on an unexplored topic: the *affinity* between the mechanism and behavior. Since subjects behave almost consistently with BEWDS under the AM but not the CM, the behavioral principle of subjects might depend on the mechanism.

The remainder of this paper is organized as follows. Section 2 explains the AM, and Section 3

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[4] In this vein, Saijo et al. (2016), who developed a working paper version of the present paper, characterized the AM using certain no-punishment and no-coercion conditions. Kimbrough and Sheremeta (2013) presented situations in which side payments assumed in the CM—collusion in a market, patent races, and R&D competition—might not be legal. Guala (2012) pointed out that there is little anthropological evidence that humankind has used private punishment.

identifies BEWDS and SPNE under the AM. Section 4 introduces the CM. Section 5 presents the experimental design. Section 6 discusses the experimental results. Section 7 concludes the paper.

2. Approval Mechanism

The AM consists of two stages. In the first stage, players 1 and 2 face a typical PD game, as presented in Fig. 1. Both players must choose either cooperation (*C*) or defection (*D*). While there might be many ways to interpret the matrix in Fig. 1, a typical interpretation in public economics is the payoff matrix of the voluntary contribution mechanism for the provision of a public good. Each player initially has $10 (or initial endowment *w*), and must decide whether to contribute the whole $10 (cooperate) or nothing (defect). The sum of the contribution is multiplied by $\alpha \in (0.5, 1)$, which is 0.7 in Fig. 1, and the benefit is enjoyed by both players, which indicates non-rivalry over the public good. If both players contribute, then the benefit to each player is (10 + 10) × 0.7 = 14. If either contributes, the contributor's benefit is 10 × 0.7 = 7, while the non-contributor's benefit, including the $10 remaining, is 10 + 7 = 17. Therefore, the payoff matrix in Fig. 1 maintains a linear structure, with non-contribution (*D*) as the dominant strategy. The bold numbers in the lower right cell denote the equilibrium payoff.

<Fig. 1 about here.>

Fig. 1 PD game

Consider now the following second stage (approval). If both players approve the other's choice in the first stage, then the payoff (or outcome) is what they choose in the PD stage. Otherwise, the payoff is (10,10), which corresponds to (*D,D*) in the first stage.[5]

There are many examples of the AM. Consider a merger or joint project undertaken between two companies. They must cooperatively propose plans in the first stage, with each then facing an approval decision in the second stage. Another example is a two-party political system. Each party chooses either cooperation (or compromise) or defection (or insistence on the party's own policy), and the parliamentary body then approves or disapproves the choice. A bicameral

[5] The AM differs from the money-back guarantee mechanism, as follows. If either player, but not both, chooses *C*, then the $10 contribution is returned to the cooperator. The money-back guarantee mechanism cannot generate (7,17), while the AM achieves (7,17) if players choose (*C*,*D*) and then both choose *y*. The same argument applies to Brams and Kilgour's (2009) concept of voting between the outcomes of all-*C* and all-*D* in order to overcome PD. The AM has an advantage in terms of welfare compared to the money-back guarantee mechanism and Brams and Kilgour's (2009) voting. To observe this, consider a case in which only player 1 is sufficiently altruistic that player 1's utility is given by (player 1's material payoff) + ρ (player 2's material payoff), $\rho > 4/3$. Assume that players know each other's payoff function. Then, the outcome of *CD* maximizes the sum of utilities of two players among four possible outcomes of the PD in Figure 1. The AM implements *CD,* while neither the money-back guarantee mechanism nor Brams and Kilgour's (2009) voting mechanism does.

system also has two stages. For example, in the negotiation process at the United Nations, negotiators from relevant countries first assemble to determine compromises, and high-ranking officials, such as presidents and prime ministers, then approve or disapprove these decisions. These examples demonstrate that adding an approval stage to resolve conflicts is widely used in society.

3. Predictions under the Approval Mechanism

3.1. Backward Elimination of Weakly Dominated Strategies

Backward elimination of weakly dominated strategies (BEWDS), which was also adopted by, for example, Kalai (1981), requires (i) subgame perfection and (ii) an understanding that players do not choose weakly dominated strategies in each subgame or in the reduced normal-form game. We now explore the subgame starting from *CC* in Fig. 2.

<Fig. 2 about here.>

Fig. 2 Four subgames in the AM

<Fig. 3 about here.>

Fig. 3 Reduced normal-form games

Suppose that player 1 chooses *y*. Then, the payoff of player 1 is 14 if player 2 chooses *y* and 10 if player 2 chooses *n*. Thus, the vector of possible payoffs is (14,10). The vector (10,10) then corresponds to player 1's choice of *n*. We say that choice *x* associated with a possible payoff vector (u,v) *weakly dominates* choice *z* associated with a possible payoff vector (s,t) if $u \geq s$ and $v \geq t$ with at least one strict inequality. Since *y* weakly dominates *n*, *n* should not be chosen. Therefore, *yy* is realized in subgame *CC*. The cell with the bold black italic values denotes this outcome. Similarly, *ny* in subgame *CD* and *yn* in subgame *DC* are realized. In subgame *DD*, since no weakly dominated strategy exists, *yy*, *yn*, *ny*, or *nn* is realized. Given the realized strategies in all subgames, we have the reduced normal-form game (Fig. 3-(i)). In this game, *C* weakly dominates *D* for both players, and hence, *CC* is the realized outcome. The same is true as long as the marginal benefit of cooperation is between 0.5 and 1.

Property 1. The AM implements cooperation in BEWDS.

3.2. Subgame Perfect Nash Equilibrium

Now, consider the SPNEs in the AM. To do this, we examine each subgame in the second stage shown in Fig. 2. The Nash equilibria (NEs) in subgame *CC* are *yy* and *nn* because of the indifference among *yn*, *ny*, and *nn*. Furthermore, *ny* and *nn* in subgame *CD*, *yn* and *nn* in subgame *DC*, and all four combinations in subgame *DD* are NEs. The cells with the bold gray italics indicate the NEs that are not BEWDS outcomes. Since the NEs in subgame *CC* are *yy* and *nn*, there are two reduced normal-form games (Fig. 3). (*C,C*) and (*D,D*) are NEs in Fig. 3-(i), and all combinations are NEs in Fig. 3-(ii). For example, *CDny* is an SPNE path.[6] Thus, we have the following property.

Property 2. The AM cannot implement cooperation in SPNE.

Although we can argue for other equilibrium selection criteria, in what follows, we restrict our attention to BEWDS and SPNE given the main purpose of this study.[7]

4. Compensation Mechanism

Next, we explain the CM developed by Varian (1994). In the first stage of the CM, each subject could offer to pay the other subject *before* the second PD stage if the latter cooperates. Then, both cooperate in the unique SPNE, as long as the payoff asymmetry in PD is within a certain range (Qin 2005). In Andreoni and Varian (1999), random-matched groups of two play a slightly asymmetric PD game for the first 15 periods and, then, play the CM from the 16th to the 40th periods. The cooperation rate of the CM was 50.5%, which is contrary to the SPNE prediction.

In the CM using PD in Fig. 1, the equilibrium offers are either three or four in the CM, and then both choose cooperation in the PD stage. On the other hand, all possible combinations, (*C,C*), (*C,D*), (*D,C*), and (*D,D*), can survive under BEWDS with an equilibrium offer of three. The BEWDS outcomes are 33*CC*, 33*CD*, 33*DC*, 33*DD*, 34*CC*, 34*CD*, 43*CC*, 43*DC*, and 44*CC*.[8] In summary, we have the following property.

Property 3. The CM implements cooperation in SPNE, but not in BEWDS.

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[6] A *path* is a list of what each player does in each stage: player 1's choice between *C* and *D*, player 2's choice between *C* and *D*, player 1's choice between *y* and *n*, and player 2's choice between *y* and *n*. For simplicity, hereafter, we write a path as *CDny* instead of (*C,D,n,y*). In the AM, we have 96 SPNEs. See Saijo et al. (2016) for more details.

[7] The risk dominance criterion, even with subgame perfection, cannot select the strategy uniquely, unlike in the case of BEWDS. The off-path prediction by risk dominance is redundant. To observe this, consider subgame *CD* in Fig. 2. According to risk dominance, an NE with greater product deviation loss is more likely to occur (e.g., Blonski and Spagnolo 2015). Since the product of loss deviating from NE (*n,y*) and that of (*n,n*) are zero, both are predicted in light of risk dominance. However, seven out of the eight observed choices in subgame *CD* are (*n,y*), as reported in Table 2.

[8] These results are due to the discreteness of strategies.

5. Experimental Procedures

We conducted the experiments at Osaka University in November 2009, March 2010, October and November 2011, and January 2012. The AM and CM had three sessions each, and PD had one session. In each session, 20 subjects played the game in 19 periods. We created 10 pairs out of the 20 subjects and seated them at computer terminals in each session. We used the z-Tree program (Fischbacher 2007). We employed complete stranger matching.[9] No subjects participated in more than one session. We recruited these subjects through whole-campus advertisements. Subjects were told that there would be an opportunity to earn money in a research experiment. Communication among the subjects was prohibited. Each subject received an instruction sheet and record sheet. The instructions were read aloud by the same experimenter.

We now explain how the AM was implemented experimentally. Before the payment periods began, we allowed the subjects 5 minutes to examine the payoff table and consider their strategies. When the period started, each subject selected A (defection) or B (cooperation) in the choice (or PD) stage, and then fed their choice into a computer and filled in his or her choice and reason on the record sheet. Then, each subject wrote the reason in a small box on the record sheet. Next was the decision (or approval) stage. Knowing the other's choice, each subject chose to either "accept" or "reject" the other's choice, and then reported the decision on the computer and record sheet. Then, each subject wrote the reason in a small box. Once all subjects 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. Subjects received no information on the choices and decisions made in the other groups. This ended one period. The experiment without the decision stage became the PD. After 19 periods of play, subjects answered a demographic questionnaire.

In the CM sessions, when a period began, subjects would proceed to the transfer stage, where they chose how many points to transfer to the opponent if the opponent chose B in the second (choice) stage. The transfer must be a nonnegative integer with an increment of 100. In the choice stage, subjects chose A or B knowing the pair of offered transfers.

6. Experimental Results

6.1. Comparison of the Approval Mechanism and Compensation Mechanism

Fig. 4 illustrates the cooperation rates of the AM, CM, and PDs per period. We used the *ex post* cooperation rate in the AM experiments.

<Fig. 4 about here.>

[9] The pairings were anonymous and determined in advance so that no two subjects were paired more than once.

Fig. 4 Cooperation rates by treatment

For example, if both chose *C* in the choice stage and one of the subjects disapproved of the other's choice in the decision stage, then we did not count their choices as cooperation. The AM achieves a high cooperation rate for periods 1–19; the cooperation rate is 90% in period 1, and at least 90% in all periods except period 14, with an average rate of 93.2%. The AM yielded a significantly higher average cooperation rate than did the CM (p-value < 0.001, Wilcoxon rank-sum test).[10] The latter yielded 63.3% in the first period and 75.2% across periods. The period-by-period Chi-square test results in Table 1 indicate that the gap in the cooperation rate between the AM and CM was sustained, especially in the first 10 periods.

As a control treatment, the PD obtained a 7.9% cooperation rate; specifically, it is 11% for the first five periods, but declines to 6% in the last five. Furthermore, no *CC* was observed among the 190 pairs of choices.[11] Both the AM and CM promote cooperation compared to the PD (p-value < 0.001 for both AM vs. PD and CM vs. PD, Wilcoxon rank-sum test).[12]

Period	1	2	3	4	5	6	7	8	9	10
AM vs. CM	0.001	0.000	0.000	0.000	0.000	0.001	0.008	0.011	0.002	0.002

Period	11	12	13	14	15	16	17	18	19
AM vs. CM	0.031	0.053	0.053	1.000	0.080	0.343	0.088	0.015	0.001

Table 1. p-values of chi-square test for each period

6.2. *Data Prediction Using Backward Elimination of Weakly Dominated Strategies versus Subgame Perfect Nash Equilibrium*

To study whether BEWDS or SPNE is a better predictor of subjects' behavior, we analyzed individual choices. We used a path as a unit of prediction and observation. Note that the abovementioned (Sections 3 and 4) theoretical properties make it difficult to establish this for the following reasons. Consider the AM: while the BEWDS path is unique (Property 1), SPNE paths are multiple (Property 2). Moreover, SPNE paths include a BEWDS path. However, the opposite holds for the CM (Property 3). With such multiplicity and overlapping equilibrium sets, it is important to consider where the data accumulate as well as the degree to which the predictions

[10] We used Andreoni and Miller's (1993) method for statistical testing. We first calculated the average cooperation rate for each subject across periods, followed by the test statistic using the averages to eliminate cross-period correlation.

[11] The cooperation rate in the PD is slightly lower than that recorded in previous experiments. For example, Cooper et al. (1996) and Andreoni and Miller (1993) found 20% and 18% cooperation rates, respectively.

[12] Additional experiments on the AM and PD, in which subjects play the game in only one period, provide similar results, suggesting that the AM works without repetition. The data and results are available upon request.

are sharp.

Selten's index of predictive success is a measure introduced and axiomatized by Selten (1991) to balance both concerns.[13] Let a mechanism and an equilibrium concept (BEWDS or SPNE) be given. The index is the difference between two components that respectively correspond to the descriptive power and parsimony of the equilibrium prediction. The first component is the pass rate r, which is the proportion of correctly predicted observations. We provide an example of r using Table 2, which summarizes predictions, observations, and Selten's indexes. Consider the AM sessions shown in panel (a). Note that there are 19 (subjects) x 10 (groups) x 3 (sessions) = 570 observations. The second column shows that the BEWDS prediction is only *CCyy* (Property 1). Since 531 out of 570 observations are *CCyy* paths, we have r = 531/570 = 0.932 for BEWDS. The second component of Selten's index is area a, which is the ratio of the number of equilibrium predictions to the total number of possible paths. Note that for each player, there are two choices in each stage (*C* or *D*, *y* or *n*) and there are $(2 \cdot 2)^2 = 16$ possible paths. Since the BEWDS prediction is only *CCyy*, we have a = 1/16 = 0.063 for BEWDS. Hence, under the AM, Selten's index for BEWDS $s = r - a = 0.932 - 0.063 = 0.869$. Note that a larger s is better and $-1 < s < 1$.

Path	BEWDS	SPNE	Obs.	Pass rate r	Area a	Selten's Index $s = r - a$
CCyy	Yes	Yes	531	0.932 (=531/570))	0.063 (=1/16)	0.869
CCnn	No	Yes	0	0.990 (=564/570)	0.625 (=10/16)	0.365
*CDny**	No	Yes	28			
*CDnn**	No	Yes	4			
DDyy	No	Yes	1			
*DDyn**	No	Yes	0			
DDnn	No	Yes	0			

(a) AM

[13] Selten's index has been used in the literature on testing revealed preference. Our notations follow those of Beatty and Crawford (2011). Forsythe et al. (1996) applied Selten's index to a voting game experiment.

Path	BEWDS	SPNE	Obs.	Pass rate r	Area a	Selten's Index $s = r - a$
33*CC*	Yes	Yes	48	0.423 (=241/570)	0.04 (=4/100)	0.383
34*CC**	Yes	Yes	58			
44*CC*	Yes	Yes	135			
33*CD**	Yes	No	5	0.577 (=329/570)	0.09 (=9/100)	0.487
33*DD*	Yes	No	0			
34*CD**	Yes	No	83			

(b) CM

Notes. a) We counted every asymmetric path (*) twice to calculate area *a* because of its permutation. b) In the CM treatment, we computed area *a* by assuming that each player chooses a transfer from {0,100,200,300,400}. The result holds for any number of possible actions of more than five in the first stage.

Table 2. BEWDS vs. SPNE by mechanism

Consider the AM and SPNE. The mark "*" indicates that the path is asymmetric, and thus, we must count its permutation. There are 10 SPNE paths (*CCyy, CCnn, CDny, DCyn, CDnn, DCnn, DDyy, DDyn, DDny*, and *DDnn*), which explain 531 + 28 + 4 + 1 = 564 observed paths. Thus, r = 564⁄570 = 0.990. On the other hand, a = 10/16 = 0.625. Hence, Selten's index $s = r - a$ = 0.990 – 0.625 = 0.365 for SPNE, which is much less than the index for BEWDS. Hence, we concluded that BEWDS is a better predictor than SPNE under the AM. Note that for SPNE, r is higher largely by the observations of *CDny*. It is natural to consider that player 2 tried to exploit player 1 in this path. On the other hand, in order for *CDny* to be an SPNE path, *nn* must occur in subgame *CC*, which are dominated actions and never occurred.

Next, we examine the CM case shown in panel (b) of Table 2. Note that the second and third columns show that the SPNE paths are included in the BEWDS paths (Property 3). BEWDS paths explain 57.7% of the path data, while SPNE paths cover 42.3%. A frequently observed non-SPNE path is *34CD*, which survives under BEWDS since player 2 is indifferent between *C* and *D* in subgame *34*. However, *CC* must be chosen so that *34* constitutes the SPNE path. To compute area a in the CM, we must fix the number of possible paths and, thus, the number of first-stage alternatives. Table 2 (b) presents the area where each player can choose a transfer from {0,100,200,300,400}, while in the experiment, subjects can offer any nonnegative multiple of 100.

Hence, the number of all possible paths under the CM is $(5 \cdot 2)^2 = 100$. Then, the area for BEWDS is 9/100 = 0.09, while that for SPNE is 4/100 = 0.04. Here, too, BEWDS yields a higher Selten's index of 0.577 − 0.09 = 0.487 than SPNE does, with an index of 0.423 − 0.04 = 0.383. However, it is noteworthy that neither SPNE nor BEWDS performs well in the CM.

7. Concluding Remarks

The present study theoretically established that the AM implements cooperation in BEWDS. We tested the theoretical predictions in an experiment, and found that the AM promotes cooperation significantly in a PD experiment, compared to the CM implementing cooperation in SPNE. Utilizing Selten's index to predictive success, we also demonstrated that BEWDS well explains data in the AM, but neither BEWDS nor SPNE does in the CM. Interestingly, this could be due to a large number of transfer options, which puts a heavy cognitive load on the subjects to find equilibria, as shown in Midler et al.'s (2015) CM experiment.

Undoubtedly, the AM does not always solve all PD games. First, it is implicitly presumed that participants must agree to use the mechanism. Second, the mechanism might need monitoring devices and/or an enforcing power; otherwise, a participant might not perform the task described in C even after two participants choose C and y. Third, we cannot apply the mechanism if the contents of C have not yet been agreed upon. For example, although many researchers have used global warming as an example of PD, countries have been negotiating actions to address climate change for more than 20 years under the United Nations Framework Convention on Climate Change without having agreed on what exactly C should be.[14]

We close by briefly mentioning some related research projects. Masuda et al. (2014) designed a minimum AM for a two-person voluntary contribution game for the provision of a public good, avoiding the failure of AM, as in the case of Banks et al.'s (1988) unanimous voting, and found that the minimum AM implements the Pareto-efficient outcome theoretically and experimentally. Second, for an n-player PD situation, Huang et al. (2017) designed the stay-leave mechanism, which leads to a behavioral mixture: BEWDS players and conditional cooperators. Third, consider a situation with at least three strategies and participants. Although a number of studies have explored this environment (Plott and Smith 2008), the gap between theory and experiments is yet to be bridged. Fourth, Saijo and Shen (2018) reported that the AM works well even with an asymmetric PD, whereas the CM does not. Finally, exploring dependence between mechanism and induced behavior among subjects is an important future research agenda, given that BEWDS explains data in the AM but not in the CM.

[14] Although many people advocated the Paris Accord, the national pledges by countries to cut emissions are voluntary and do not involve penalty. "At best, scientists who have analyzed it say it will cut global greenhouse gas emissions by about half the required amount to avert a potential increase in atmospheric temperatures of 2 degrees Celsius or 3.6 degrees Fahrenheit" (NYTimes, 2015).

Conflict of Interest: The authors declare that they have no conflict of interest.

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

Player 2

Player 1	*Y*	*n*
y	***14,14***	10,10
n	10,10	***10,10***

Subgame *CC*

	y	*n*
y	7,17	10,10
n	***10,10***	***10,10***

Subgame *CD*

	y	*n*
y	17,7	***10,10***
n	10,10	***10,10***

Subgame *DC*

	y	*n*
y	***10,10***	***10,10***
n	***10,10***	***10,10***

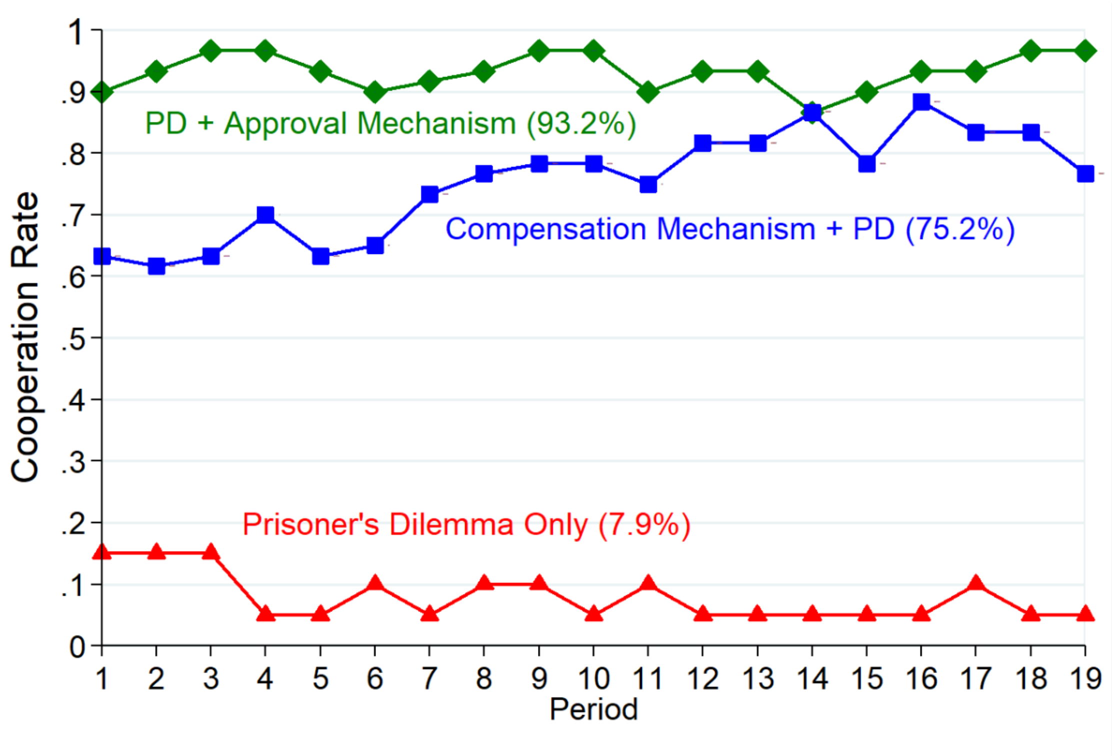
Subgame *DD*

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

(i) *yy* in subgame *CC*

		Player 2	
		C	*D*
Player 1	*C*	***10,10***	***10,10***
	D	***10,10***	***10,10***

(ii) *nn* in subgame *CC*



Cooperation Rate
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
PD + Approval Mechanism (93.2%)
Compensation Mechanism + PD (75.2%)
Prisoner's Dilemma Only (7.9%)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Period