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The minimum approval mechanism implements the efficient public good allocation theoretically and experimentally

Takehito Masuda [a,b,*], Yoshitaka Okano [a], Tatsuyoshi Saijo [a,c]

[a] *Research Center for Social Design Engineering, Kochi University of Technology, Tosayamada, Kami, Kochi 782-8502, Japan*
[b] *Graduate School of Economics, Osaka University, 1-7 Machikaneyama, Toyonaka, Osaka 560-0043, Japan*
[c] *Center for Environmental Innovation Design for Sustainability, Osaka University, 2-1 Yamada-oka, Suita, Osaka 565-0871, Japan*

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ABSTRACT

We propose the minimum approval mechanism (MAM) for a standard linear public good environment with two players. Players simultaneously and privately choose their contributions to the public good in the first stage. In the second stage, they simultaneously decide whether to approve the other's choice. Both contribute what they choose in the first stage if both players approve; otherwise, both contribute the minimum of the two choices in the first stage. The MAM implements the Pareto-efficient allocation in multiple solution concepts including backward elimination of weakly dominated strategies (BEWDS), limit logit agent quantal response equilibrium, subgame perfect minimax regret equilibrium, level-*k* thinking, and diagonalization heuristics. Moreover, the MAM is unique under plausible conditions. Overall, contributions in the MAM experiment averaged 94.9%. Quantifying subjects' responses to the questionnaire reveal heterogeneous reasoning processes and highlight the importance of developing mechanisms that implement the desired social choice outcome in multiple solution concepts.

1. Introduction

The free-rider problem lies at the heart of public good provision. To solve this problem, theorists have traditionally concentrated on designing mechanisms yielding efficient outcomes, given that players are self-interested. In this mechanism design or implementation approach, individual theorists have discretion over which equilibrium concept or behavioral rule to use, such as dominant strategy equilibrium, Nash equilibrium, or subgame perfect Nash equilibrium (SPNE). However, recent experimental results have raised questions concerning this fundamental assumption.[1] It is also widely observed that experimental subjects are heterogeneous in their motive to choose their contributions to the public good.

We offer an alternative approach, multiple implementations, in order to bridge gaps between the theory and experiments. That is, public good mechanisms should be robust to as many as possible equilibrium concepts or behavioral rules. More precisely, we design the minimum approval mechanism (MAM) that implements the symmetric Pareto-efficient allocation in multiple solution concepts for linear public good environments with two players.

Abbreviations: MAM, minimum approval mechanism; BEWDS, backward elimination of weakly dominated strategies; MCM, mate choice mechanism.

* Corresponding author at: Research Center for Social Design Engineering, Kochi University of Technology, Tosayamada, Kami, Kochi 782-8502, Japan. Fax: +81 887 57 2366.

E-mail addresses: takehitomasuda@gmail.com (T. Masuda), okano.yoshitaka@kochi-tech.ac.jp (Y. Okano), tatsuyoshisaijo@gmail.com (T. Saijo).

[1] See Chen (2008) for an excellent survey.

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The MAM consists of two stages. Each player chooses his/her contribution in the first stage, following which each player observes the other's choice and approves or disapproves the same. If both players approve, their final contributions are what they chose in the first stage. If either disapproves, both finally contribute the minimum of their first-stage choices.

Under the MAM, both players fully contribute in all five equilibrium concepts or heuristics: (i) backward elimination of weakly dominated strategies (BEWDS; Saijo et al., 2013),[2] (ii) limit logit agent quantal response equilibrium (limit LAQRE; McKelvey and Palfrey, 1995, 1998), (iii) subgame perfect minimax regret equilibrium (SPMRE; Renou and Schlag, 2011), (iv) level-k thinking (Costa-Gomes and Crawford, 2006), and (v) diagonalization heuristics.

Moreover, we show that the MAM is a unique BEWDS-implementing approval mechanism, satisfying the following natural properties. *Forthrightness* requires that the outcome must be what players choose whenever both approve the other's first-stage choices. *Voluntariness* mandates that no player is forced to finally contribute more than what he/she chooses in the first stage.[3] *Monotonicity* states that final contributions increase as their first-stage choices increase.

In experiments under the perfect stranger matching protocol, we observe, as predicted, a rapid convergence to efficient allocation in the MAM. Subjects successfully sustained high average contribution rates, beginning with 76.9% in the first period and ending with 89.7% in the final period. The overall average contribution rate is 94.9%.[4] Our experimental results of the MAM are in sharp contrast with those of existing mechanisms that need dozens of iterations to converge to the efficient Nash equilibrium in experiments. We also conduct experiments for the mate choice mechanism (MCM) of Saijo et al. (2013), which theoretically does not work in our public good environment and observe that the average contribution fluctuates within a middle range.

In order to capture subjects' reasoning processes, we apply a coding scheme similar to the one of Cooper and Kagel (2005). Two coders independently quantified subjects' responses to open questions during and after the session. The coding confirms that subjects are heterogeneous in their motive. In particular, 20.0% of subjects in the MAM are deemed to have used diagonalization heuristics. Moreover, 16.7% and 11.7% of subjects in the MAM and MCM, respectively are deemed to minimize regret. Finally, 21.7% and 45.0% of subjects in the MCM are deemed to have followed level-1 and level-2 thinking, respectively.

Our approach differs from much of the experimental research on the public good mechanism, which thus far has mainly focused on evaluating mechanism designs based on dominant strategy equilibrium, Nash equilibrium, or SPNE. For dominant strategy mechanisms, Attiyeh et al. (2000) found that subjects in the pivotal mechanism frequently misrepresent their private information and become stuck at a weakly dominated Nash equilibrium. To solve this problem, Saijo et al. (2007) introduced secure implementation (or double implementation in dominant strategy equilibrium and Nash equilibrium). Further, Cason et al. (2006) experimentally showed that the frequency of dominant strategy play was significantly increased in a secure Groves–Clarke mechanism relative to a nonsecure pivotal mechanism, although the former's frequency was only slightly over 80%.

The Groves–Ledyard (1977) and Walker (1981) mechanisms have difficulty in attaining efficient Nash equilibria in one-shot play, because of subjects' bounded rationalities.[5] Andreoni and Varian (1999) reported similar results for Varian's (1994) extensive form mechanism with the unique SPNE. Chen and Plott (1996), Chen and Tang (1998), Chen and Gazzale (2004), Healy (2006), and Healy and Mathevet (2012) characterized the stable mechanisms to achieve efficient Nash equilibria as rest points of various learning dynamics. Nonetheless, these studies still required dozens of repetitions, which may not be feasible in practical situations. A notable exception is Falkinger et al. (2000), who observed that under Falkinger's (1996) mechanism, contributions approached the efficient Nash equilibrium in only a few periods.[6]

The remainder of this paper is organized as follows. Section 2 overviews the MCM proposed by Saijo et al. (2013), introduces the MAM with examples, and presents the implementation results. Section 3 describes the proof of the uniqueness of the MAM. Section 4 argues in favor of the MAM's robustness. Section 5 describes the experimental design. Section 6 discusses the experimental results. Section 7 provides an analysis of subjects' responses to the open-ended questionnaire. Section 8 discusses further implications and concludes.

2. The model and the MAM

Consider a voluntary contribution mechanism (VCM) in the provision of a public good with two players. Each player i has an initial endowment $w > 0$, and he/she must decide the contribution $s_i \in S = [0, w]$. The sum of the contribution is multiplied by $\alpha \in (0.5, 1)$, and the benefit passes to every player, which expresses the non-rivalness of the public good. That is, player i's payoff is $u_i(s_i, s_j) = (w - s_i) + \alpha(s_i + s_j)$, $j \neq i$. Then, $s_1 = s_2 = 0$ is the dominant strategy equilibrium, and hence, no public good is provided.

[2] As Saijo et al. (2013) noted, Kalai (1981) used BEWDS.

[3] In other words, we only provide refunds to players, rather than using coercive power.

[4] We obtained a similar result in the simplified MAM (SMAM) treatment, in which the player with the higher first-stage choice alone can proceed to the second stage.

[5] See Chen and Plott (1996) and Chen and Tang (1998).

[6] Contributions averaged 90.5% of subjects' endowments in experiments with linear payoffs. However, this mechanism proportionally taxes or subsidizes to the extent of the deviation of a player's contribution from the mean contribution, and hence, some players are forced to contribute more than they choose.