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Near-efficient equilibria in contribution-based competitive grouping

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ABSTRACT

We examine theoretically and experimentally how competitive contribution-based group formation affects incentives to free-ride. We introduce a new formal model of social production, called a "Group-based Meritocracy Mechanism" (GBM), which extends the single-group-level analysis of a Voluntary Contribution Mechanism (VCM) to multiple groups. In a GBM individuals are ranked according to their group contributions. Based on this ranking, participants are then partitioned into equal-sized groups. Members of each group share their collective output equally amongst themselves according to a VCM payoff function. The GBM has two pure-strategy Nash equilibria. One is non-contribution by all; this equilibrium thus coincides with the VCM's equilibrium. The second equilibrium is close to Pareto optimal. It is asymmetric and quite complex from the viewpoint of experimental subjects, yet subjects tacitly coordinate this equilibrium reliably and precisely. Extensions of the basic GBM model to incorporate various features of naturally occurring group formation are suggested in the conclusion.

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1. Introduction

Experimental studies exploring endogenous group formation show that the degree of excludability of public goods or team goods (Buchanan, 1965) is not the only factor that influences group contributions. The method by which players are assigned to their cooperative units might be equally important. Competitive grouping based upon individuals' group contributions can significantly increase cooperation and efficiency in a variety of experimental environments.[1] These results are rather intuitive since outside the laboratory it is commonly observed that those willing or able to make high team contributions tend to select each other and attempt to avoid free-riders.

This paper introduces the "Group-based Meritocracy Mechanism" (GBM), a basic formal model of contribution-based group formation that relies on material self-interest only. The GBM can be regarded as a multiple-group extension of the Voluntary Contribution Mechanism (VCM, see, e.g. Isaac et al., 1985). The VCM, as the standard basic theoretical and experimental model of a social dilemma, applies to a single group and bypasses the important question of how groups actually form.

To our knowledge the GBM is the first formal and complete approach to contribution-based group formation[2] where cooperation is part of an equilibrium strategy in a one-shot game.[3] The GBM meets the following minimum requirements for a formal model of competitive contribution-based grouping: **1)** group membership is competitively and solely based on individual contributions, **2)** the equilibrium analysis extends across all players and all groups, since players compete for membership in groups that vary in their payoff, **3)** in the causal chain, the contribution decision precedes grouping and the calculation of the associated payoff. In the current paper, we examine the basic GBM mechanism

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[1] See Ehrhart and Keser (1999) for an early study. For recent studies see e.g. Ahn et al. (2008), Cabrera et al. (2007), Charness and Yang (2009), Cinyabuguma et al. (2005), Croson et al. (2007), Gächter and Thöni (2005), Güth et al. (2007), Page et al. (2005). Maier-Rigaud et al. (2010) provide a recent overview. Contribution-based grouping also has an impact if players do not even know that they are being grouped (e.g., Ones and Putterman, 2007; Gunnthorsdottir et al., 2007). See Gunnthorsdottir (2009) for a comparison of grouping that subjects know or do not know about.

[2] Our model differs from Tiebout (1956) in that preferences are homogeneous, and grouping is contribution-based rather than based on differences in preferences.

[3] It is well known that in infinitely or indefinitely repeated games, cooperation can be sustained as an equilibrium through trigger strategies (see, e.g., Axelrod, 1986).

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theoretically and experimentally, and find that in the controlled conditions of the laboratory the payoff-dominant Nash equilibrium (Harsanyi and Selten, 1988) is an accurate predictor of aggregate behavior.

1.1. Overview

In Section 2 we describe the GBM and derive its two pure-strategy equilibria. One is highly efficient while the other is inefficient but minimizes strategic risk. Applying the equilibrium selection principle of payoff dominance (Harsanyi and Selten, 1988)[4] one can make a precise prediction about GBM participants' aggregate behavior: the more efficient equilibrium should be selected, and contribution-based grouping should overcome the social dilemma within all but one of the groups in the system. Section 3 describes the experimental test of the model. The results in Section 4 provide strong empirical support for the equilibrium prediction, payoff dominance, and the efficiency-enhancing effects of contribution-based grouping. In the aggregate, subjects tacitly coordinate the payoff-dominant equilibrium even though it is asymmetric and somewhat complex. Section 5 compares and contrasts our behavioral findings about equilibrium selection, tacit coordination of asymmetric equilibria, and the effect of contribution-based grouping to experimental findings from other games. In the concluding Section 6 we address the limitations of the model, suggest extensions, and speculate about field applications.

2. The Group-Based Meritocracy Mechanism (GBM)

Group assignment in a GBM is competitively based on individual contributions. Within each group, payoffs are determined via a VCM. We first describe this within-group (VCM) interaction, then describe the competitive group assignment that distinguishes the GBM from the VCM.

2.1. Payoff calculation within groups

In a VCM, n group members decide simultaneously how much of their individual endowment w to keep for themselves, and how much to contribute to a group account. Contributions to the group account are multiplied by a factor g, which represents the benefits from cooperation, before being equally divided among all n group members. The rate g/n is the marginal per capita return (henceforth MPCR and denoted by m) to each group member from an investment in the group account. As long as $1>m>1/n$, the game is a social dilemma: efficiency is maximized if all participants contribute fully, but each individual's dominant strategy is to contribute nothing to the group account.

2.2. Competitive grouping

The VCM models a single group and bypasses the question of how the group formed. In a standard experimental VCM the group assignment is therefore random. The GBM model in contrast incorporates competitive group membership based on individual contributions. Once all N participants have decided their group contribution, they get ranked accordingly, with ties broken at random. Based on this ranking, participants are then partitioned into G equal-sized groups, so that the highest ranking $n=N/G$ players are grouped together, then the next n players, and so on. Finally, individual earnings are computed by the same method as in a standard VCM and taking into account to which group a participant has been assigned.[5] The GBM game has two[6] pure-strategy[7] equilibria that differ in efficiency.

2.3. Equilibrium of non-contribution by all

This equilibrium reflects the fact that the GBM's within-group interaction retains social dilemma properties. With competitive grouping added, these properties are however attenuated. Non-contribution by all is no longer a dominant-strategy equilibrium as in the VCM, but remains a best-response equilibrium. Note that this equilibrium involves no strategic risk.

2.4. The Near-efficient Equilibrium (NEE)

The "Near-efficient Equilibrium" (henceforth NEE) is payoff-dominant (Harsanyi and Selten, 1988, Ch. 3.6), close to Pareto optimal, and asymmetric. Almost all players contribute their entire endowment; only z players contribute nothing. The exact value of z depends on the MPCR m as well as on n, G, and N. However, z is always smaller than the group size n. Hence, the NEE asymptotically approaches full efficiency as G gets large.

We next provide an intuitive account of the NEE, assuming a continuous strategy space. (For a formal analysis see Online Appendix A). We call a subset of players whose group contributions are identical a Class. Class C_1 is a subset of players containing the c_1 highest contributors; the next class, C_2 contains the c_2 players who contribute less, and so on. We refer to the group containing the highest-ranked contributors as Group 1, to the next group as Group 2, and so on; Group G is the last group with the lowest contributors.

(**1**) Identical positive contribution by all is not an equilibrium since any one player would have an incentive to reduce her contribution to zero. Thus, in an equilibrium with positive contributions there must be more than one class.

(**2**) Group 1 can only contain players of one class, C_1. If it contained players from two or more classes, any C_1 player would have an incentive to decrease her contribution as long as she remains in Group 1. Similarly, c_1 must be larger than n and not fully divisible by n else again, any C_1 player could decrease her contribution without affecting her group membership.

(**3**) It follows from (1) and (2) that if an equilibrium with positive contributions exists, some C_1 players are grouped with C_2 players in a *mixed group*.[8]

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[4] The *payoff-dominant equilibrium* is a collectively rational solution in which each and every player earns more than at any alternative equilibrium point (Harsanyi and Selten, 1988, p. 81, 356). Harsanyi and Selten argue that since each and every player is better off with such an equilibrium (compare this to a Pareto dominant equilibrium where just one player must be better off), a payoff-dominant equilibrium should be selected from among multiple equilibria even if this requires mutual trust and coordinated expectations to offset any strategic risk that might be involved.

[5] The GBM shares features with a VCM-type treatment by Gunnthorsdottir et al. (2007; see also Gunnthorsdottir, 2001) but there are important differences: Gunnthorsdottir et al. explore individual tendencies toward reciprocity or defection and create a purposefully vague and brief version of the VCM into which subjects, *uninformed of the contribution-based grouping*, project their personality with regard to group contributions. The current study in contrast is designed to test an equilibrium prediction. Therefore, *all rules of the game are common knowledge*. In a comparison of known and unknown contribution-based groupings Gunnthorsdottir (2009) finds that both on the individual and aggregate level, subjects react very differently to these distinctly different experimental settings designed to answer different questions.

[6] See the Theorem at the end of this section for borderline cases in which there are one or three.

[7] Additionally and depending on the parameters, there exist mixed-strategy equilibria. Their strategy frequencies are distinct from the NEE frequencies. Mixed strategies are beyond the scope of this paper since: **1**) Subjects coordinated a pure-strategy equilibrium (see Section 4 incl. fn. 19 for the results of tests showing that subjects do not play mixed strategies). **2**) This finding is not surprising since mixed strategies are intuitively implausible when pure equilibrium strategies are available and there is no particular need to play unpredictably (see, e.g., Kreps, 1990, pp. 407-410; Aumann, 1985, p.19). **3**) Even in games with a *unique* equilibrium in mixed strategies, proper mixing (both the right proportions of choices and their serial independence) is usually beyond regular subjects' abilities (see e.g., Palacios-Huerta and Volij, 2008; Walker and Wooders, 2001; Brown and Rosenthal, 1990; Erev and Rapoport, 1998).

[8] Since C_1 players are tied in the ranking by contribution, a random draw determines their exact grouping. When calculating her expected payoff a C_1 player takes into account that she could end up in the mixed group with players who contribute less.

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