The meritocracy as a mechanism to overcome social dilemmas

Anna Gunnthorsdottir and Roumen Vragov and Kevin Mccabe

City University NY

10. February 2007

THE MERITOCRACY AS A MECHANISM TO OVERCOME SOCIAL DILEMMAS

Keywords: social dilemmas, Nash equilibrium, non-cooperative games, coordination, mechanism design, experiment.

JEL Classification: C72, C92

ABSTRACT

A new mechanism that substantially mitigates social dilemmas is examined theoretically and experimentally. It resembles the voluntary contribution mechanism (VCM) except that in each decision round subjects are ranked and then grouped according to their public contribution. The game has multiple mostly asymmetric, Pareto-ranked pure-strategy equilibria which are rather counterintuitive, yet experimental subjects tacitly coordinate the payoff-dominant equilibrium reliably and quite precisely. In the VCM grouping is random which, with its arbitrary relation to contribution corresponds to any grouping unrelated to output, for example grouping based on race or gender. The new mechanism resembles a meritocracy since based on how much they contribute; participants are assigned to strata that vary in payoff. The findings shed light on the nature of merit-based social and organizational grouping and provide guidelines for future research and application.

I. INTRODUCTION

Sorting and grouping of similar types are ubiquitous in human communities. As pointed out by Schelling (1971), an important factor that determines the exact nature of social segregation is the grouping and stratification criteria that social units such as organizations and societies actually apply. Throughout history, stratification has most often been based on arbitrary criteria such as gender, race, class, heritage, nepotism or cronyism, which are unfair and quite inefficient since they usually fail to place the best suited agent into a given position, and are unrelated to a person's output.

Modern organizations and contemporary societies increasingly reject such arbitrary criteria and are becoming meritocracies, where grouping and stratification is competitively based on individual contributions. This development has been helped along in the past century or so by equal-rights movements, scholarship programs, and increasingly global, and hence more intense, competition in education and business. Talent searches for outstanding workers or graduate students are becoming more geographically balanced, and performance reviews in organizations more extensive and systematic. Labor markets, the hiring and promotion systems of organizations, education systems[1], and even immigration policies[2] increasingly take on the features of a meritocracy. With the resulting increase in competitiveness of these social units, units that still apply sorting and segregation systems that are unrelated to output and make them less productive and competitive[3] can be expected to weaken, and either change or disappear. [4]

---

[1] For example, in order to increase their intellectual competitiveness the impact of legacy preferences in Ivy League schools was decreased; other non-performance related intake criteria common in the early 20th century in order to control the ethnic and gender composition of the student body were abolished (Karabel, 2005).

[2] For example, Australia offers preferential entry for skilled immigrants.

[3] An early example is 13th century Mongol general Genghis Khan, who conquered large regions of Asia. He accepted all warriors of proven ability into his army, regardless of their origin.

[4] For example Singapore, among the most successful Asian countries by most standards, seceded from Malaysia in 1965 because it rejected ethnic quotas in the assignment of social and professional roles in favor of meritocratic principles.

Our results show that in addition to placing the most able person into a given position, and being often perceived as fairer than other stratification systems, meritocracies have yet another advantage over arbitrary stratification: arbitrary stratification generates an incentive for everyone to free-ride since an individual's contribution has in the extreme case, no impact at all on his strata membership. Examples would be caste systems, or the pre-revolutionary social structure of France. A meritocracy on the other hand, as our theoretical analysis (Section II) and experiments (Sections IV and V) show, can be an effective mechanism to substantially reduce free-riding in an organization or society. The theoretical analysis also sheds some light on existing experimental results (reviewed in Section III) about the effectiveness of competitive sorting as a means of attenuating social dilemmas.

II. THEORY

We model a meritocracy as a variation of the Voluntary Contribution Mechanism (VCM) (Isaac, McCue & Plott, 1985), which has become a standard model to explore free-riding. Participants are randomly assigned to groups of fixed size n. Group members then each decide simultaneously and anonymously how much of their funds to keep for themselves, and how much to contribute to their group account. Inputs into the group account are multiplied by a factor $g > 1$[5] representing the benefits from cooperation, before being equally divided among all group members. As long as $g < n$ the game is a social dilemma since efficiency is maximized if all participants contribute fully, but each individual's dominant strategy is to keep his endowment for herself while receiving her share of the group account. The VCM's widely replicated result is that the equilibrium of

[5] We assume without loss of generality that the multiplication factor for the private account is simply 1.

noncontribution by all is all but reached after about ten repetitions (See, e.g., Ledyard, 1995; Davis and Holt, 1993).

The key difference between the VCM and the Meritocracy Mechanism introduced here (henceforth, MM) is that in a standard VCM participants are randomly assigned to groups. In its effects on incentives this is comparable to grouping by criteria unrelated to individuals' contribution, such as race or gender. In the MM in contrast, group membership is systematically based on individuals' contributions to the group account. At each round, aall MM participants get ranked according to their contribution decision. Only thereafter and based on this ranking, are participants partitioned into equal-sized groups. For the equilibrium analysis of the MM game it is important to note that any ties for group membership are broken at random. In the decision round's final step, individual earnings are computed taking into account to which group a subject has been assigned. All this is common knowledge.

Since the MM is not just about a single group but about a mini-society consisting of several units, it differs from the VCM in how members of a cooperative group are modeled within their larger society: In the standard VCM each arbitrarily composed group is modeled in isolation. In the MM all socially mobile members of a community are linked via a cooperative -competitive mechanism in which they, with their contribution decisions, compete for membership in strata with potentially different collective output and payoffs. The MM's equilibrium analysis (See Section II.A for the formal analysis) must therefore cover multiple groups. This increases the model's realism. Under naturally occurring circumstances too, cooperative groups do not exist in isolation but are in the end part of a larger social fabric.[6]

[6] The assumption of fixed group size (just as in the VCM) might at first appear quite stylized for a model designed to represent social stratification. However, social stratification often implies fixed group (stratum) size. Examples are journal space in tier 1 journals or labor markets in which there are usually a fixed number of jobs available, such as the annual supply of junior positions at Research 1 universities. In such cases, if

In contrast to the VCM with its dominant strategy equilibrium of non-contribution by all, the MM has multiple Pareto-ranked equilibria. Non-contribution by all is one of them, but with the introduction of competitive sorting it becomes merely the least efficient among several best-response equilibria. All other pure strategy equilibria are asymmetric: a significant number of players make a positive contribution while the remainder contributes nothing.[7] As shown in Table 1 (columns 1-3) the exact number of these "relatively efficient" asymmetric equilibria, their number of contributors b and their positive contribution s_i* depend on g/n, which is the marginal per capital return from the group account (henceforth, MPCR). The Table lists the relatively efficient equilibria for two sets of parameters commonly used in VCM experiments, which allows a good comparison with pre-existing data. For each set of parameters, the most efficient equilibrium (shaded cells) is close to Pareto optimal, and as Section II.A below shows formally, there is usually one such equilibrium for any MPCR condition.[8] Note that in all equilibria listed in Table 1 the number of players who contribute, b is not divisible by the group size n. The fact that not all contributors can therefore be in a homogeneous group is crucial to the structure of the relatively efficient equilibria. Since ties among contributors with regard to group membership are solved at random, the equilibrium-payoffs to cooperators, (and, in cases where $b>n$, to free-riders as well) are expected, rather than secure, payoffs. It can be verified from the Table (columns 4-7) that in every relatively efficient equilibrium **A)** the expected payoffs from contributing and from not contributing are such that no player has an incentive to unilaterally deviate, and **B)** every player is better off than in a situation in

there are more "perfect" candidates than positions, a perfect candidate will reach the top stratum only with probability <1.

[7] In addition there exist mixed-strategy equilibria. The question of the applicability of mixed strategy equilibria in predicting behavior has so far produced unclear and context dependent results. (See, e.g., Walker & Wooders (2001), Estes (1964) for evidence that humans cannot randomize, Rapoport & Budescu (1997) for evidence of restricted randomization, but Rapoport & Boebel (1992) and O'Neill (1987) or some indications to the opposite. Most importantly for the case of the MM however, the behavioral data (Section V) do not support mixed strategies, and thus echo the results from Market Entry games, which are somewhat similar to the MM in structure, and are reviewed in Section III.

[8] See the Theorem in Section II.

which no one contributes. The next section formally derives all pure strategy equilibria in the MM.

II.A. Formal equilibrium analysis

As in the VCM, the meritocracy environment includes $i = 1, \ldots, N$ players, each with a positive endowment w_i. As in the VCM, each participant i makes an integer contribution s_i to the group account and leaves the remainder $w_i - s_i$ in his private account. All i are then ranked according to their contribution decisions with ties broken at random, and divided into $G < N$ ($G > 2$) groups of equal size n. Subjects with the highest n contributions are put into group 1, subjects with the second highest n contributions are put into group 2 and so on. Let G_i be the group in which subject i is placed, and σ_{G_i} be the sum of the contributions of all n-1 subjects in subject i's group except subject i. The pay-off function for subject i is the basic VCM payoff function:

$$\pi_i(s_i, \sigma_{G_i}) = (w_i - s_i) + m(\sigma_{G_i} + s_i) \qquad \textbf{(1)}$$

The parameter m () is the marginal per-capital return (MPCR) from an investment into the group account. If $m > \frac{1}{n}$, it is Pareto optimal for each subject to make the highest possible contribution to the group account, in which case all groups of subjects will have the same total contribution and the same return. In the standard VCM environment with random group assignment, as long as $m < 1$ and for any configuration of contributions by the other participants, each player i maximizes her individual payoff by contributing nothing to the group account. Hence, the dominant strategy is $s_i = 0$ for all $i = 1, \ldots, N$. This is also the least efficient allocation of resources from among all possible allocations. We next show that the MM's competitive group assignment based on individual contribution decisions increases the number of pure strategy Nash equilibria.

For notational simplicity, we drop the index *G* from σ_{G_i}, and denote by σ_i the sum of group account contributions of all other subjects in the same group as *i* except subject *i*. We proceed to find all pure strategy Nash equilibria of the MM by elimination, using the following three Lemmata:

Lemma 1: Any set of pure strategies *S* in which there is at least one player *i* with strategy $s_i > 0$ who is in group G_i with probability 1 and will stay with probability 1 in the same group by playing $s_i - 1$ cannot be a pure strategy Nash equilibrium.

Proof: Using (1), the expected payoff of strategy s_i if player *i* is in group G_i for certain is $\pi_i(s_i) = w_i + m\sigma_i + (m-1)s_i$. The expected payoff for player *i* of strategy s_i-*1* if she stays in the same group for certain is $\pi_i(s_i - 1) = w_i + m\sigma_i + (m-1)s_i + 1 - m > \pi_i(s_i)$ because $m < 1 \Rightarrow$ Player *i* has an incentive to play s_i-1; so s_i cannot be a part of a pure strategy Nash equilibrium.

Observation 1: Lemma 1 also applies in cases when player *i* could be classified as a member of any of several groups as long as the level of contribution of the other players in these groups is the same within their group.

Lemma 2: Any set of pure strategies *S* in which there is at least one player *i* with strategy $s_i > 0$ who is in group G_i with probability 1 and will stay with some probability $p > 0$ in the same group by playing $s_i - 1$ cannot be a pure strategy Nash equilibrium.

Proof: Using (1), the expected payoff of strategy s_i if player *i* is in group G_i for certain is $\pi_i(s_i) = w_i + m\sigma_i + (m-1)s_i$. The expected payoff of player *i* when playing s_i-*1* is $\pi_i(s_i - 1) = w_i - s_i + 1 + m(s_i - 1) + pm\sigma_i + (1-p)m\sigma_{i-1}$. A Nash Equilibrium requires that

$\pi_i(s_i) \geq \pi_i(s_i - 1)$. This is equivalent to

$w_i + m\sigma_i + (m-1)s_i \geq w_i - s_i + 1 + m(s_i - 1) + pm\sigma_i + (1-p)m\sigma_{i-1}$ or

$$1 - m \leq (1-p)m(\sigma_i - \sigma_{i-1}) \quad \textbf{(2)}$$

If we have assumed that player *i* stays with some probability in the same group by playing s_i*-1*, then there are other players with that same strategy in the group directly below. Let us pick one of these players and call her player *j*. We know that $s_j = s_i - 1$. The current expected payoff of player *j* is $\pi_i(s_j) = w_j - s_i + 1 + m(s_i - 1) + rm\sigma_i + (1-r)m\sigma_{i-1}$ where *r* is the probability that player *j* will be assigned to the higher group together with *i*. If player *j* raises her contribution by 1, then she will be in the same group as *i* for certain. Player *j*'s pay-off in this case is $\pi_i(s_j + 1) = w_j - s_i + ms_i + m\sigma_i$. A Nash Equilibrium requires that

$\pi_i(s_j) \geq \pi_i(s_j + 1)$. This is equivalent to

$w_j - s_i + 1 + m(s_i - 1) + rm\sigma_i + (1-r)m\sigma_{i-1} \geq w_i + m\sigma_i + (m-1)s_i$ or

$$1 - m \geq m(1-r)(\sigma_i - \sigma_{i-1}) \quad \textbf{(3)}$$

Combining requirements (2) and (3), it is obvious that under a pure strategy Nash equilibrium it must be the case that $r \geq p$ (Assuming $\sigma_j - \sigma_{j-1} > 0$).

At the same time we know that *p* equals the number of slots available for strategy s_i*-1* in the higher group if player *i* decreases his contribution divided by the number of players that would be contributing s_i*-1*. We express this as $p = \dfrac{x^h{}_{s_i-1} + 1}{x_{s_i-1} + 1}$. At the same time *r* is equal to the number of slots available for strategy s_i *-1* in the higher group divided by the number of players that are currently contributing s_i-*1*. We define this as $r = \frac{x^h_{s_i-1}}{x_{s_i-1}}$. Since one can obtain the fraction *p* from the fraction *r* by adding 1 to the numerator and the denominator, it can be verified that $p > r$. This, however, is in direct contradiction to the combined (2) and (3) above, which require that $r \geq p$. This means that a Nash Equilibrium in pure strategies does not exists under the conditions of Lemma 2 because either *i* or *j* will always have an incentive to deviate.

Lemma 3: Any strategy set S in which every player *i* plays a strategy $s_i > 0$ and is classified into group *j* with probability $p_i > 0$ and into group *j-1* with probability $1\text{-}p_i$ cannot be a pure strategy Nash Equilibrium (Assuming $\sigma_j - \sigma_{j-1} > 0$).

Proof: The condition in Lemma 3 implies that for all players there can be only two different strategies s_i and s_k ($s_i > s_k$) and the number of players using strategy s_i (or s_k) cannot be divisible by *n*. The condition also implies that the maximum possible p_i or $p_k = \frac{n}{N} < \frac{1}{2}$.

Player *k*'s expected payoff is $\pi_k(s_k) = w_k - s_k + ms_k + p_k m\sigma_j + (1-p_k)m\sigma_{j-1}$. If player *k* increases her contribution by 1, she will be classified into the higher group for sure so $\pi_k(s_k + 1) = w_k - s_k - 1 + ms_k + m + m\sigma_j$. The Nash equilibrium requires that $\pi_k(s_k) \geq \pi_k(s_k + 1)$. This is equivalent to

$w_k - s_k + ms_k + p_k m\sigma_j + (1-p_k)m\sigma_{j-1} \geq w_k - s_k - 1 + ms_k + m + m\sigma_j$ or

$$1 - m \geq m(1-p_k)(\sigma_i - \sigma_{i-1}) \qquad \textbf{(4)}$$

If player *k* decreases her contribution to 0, she will be classified into the lower group for sure; So $\pi_k(0) = w_k + m\sigma_{j-1}$. The Nash equilibrium requires that $\pi_k(s_k) \geq \pi_k(0)$. This is equivalent to $w_k - s_k + ms_k + p_k m\sigma_j + (1-p_k)m\sigma_{j-1} \geq w_k + m\sigma_{j-1}$ or

$$1 - m \leq \frac{1}{s_k} mp_i(\sigma_i - \sigma_{i-1}) \tag{5}$$

Combining (4) and (5) and the restriction that p_k is less than ½ results in $s_k < 1$, which is not permitted since we are investigating discrete strategies >0.

Observation 2: Lemmata 1, 2, and 3 do not apply if $s_i = 0$ for all *i*. However, it is easy to show that such a configuration is a Nash equilibrium in pure strategies since no player has an incentive to deviate.

Observation 3: The only points of the strategy space not yet eliminated by Lemmata 1, 2 and 3 are the ones in which $b > n$ players use some strategy $s_i > 0$, while the remaining N-b players use strategy 0 and $q = b \bmod n > 0$.

Equilibrium requirements

Keeping in mind Observations 2 and 3 we can characterize all pure strategy equilibrium requirements. The expected payoff of player *i* is

$\pi(s_i) = w_i - s_i + ms_i + m\dfrac{b-q}{b}(l-1)s_i + m\dfrac{q}{b}(q-1)s_i$. If player *i* increases his contribution by one his pay-off will be $\pi(s_i + 1) = w_i - s_i - 1 + m + ms_i + m(n-1)s_i$. If player *i* decides to lower his contribution to 1 then his pay-off is $\pi(1) = w_i - 1 + m + m(q-1)s_i$; finally, if player *i* decides to go to zero, there are two cases to consider: When $b < N$-n , his payoff is $\pi(0) = w_i + m\dfrac{l-q}{N-b+1}(q-1)s_i$ and when $b > N$-n, his pay-off is $\pi(0) = w_i + m(q-1)s_i$.

Hence, we can now generalize the three conditions, (6), (7), and (8), that characterize the pure strategy Nash equilibrium from Player *i*'s viewpoint. They are the following:

$$m \le \frac{1}{1+\frac{q}{b}(n-q)s_i} \text{ if } s_i < \overline{w} \text{ where } \overline{w} \text{ is the upper bound of the strategy set} \tag{6}$$

$$m \ge \frac{s_i - 1}{s_i - 1 + s_i \frac{b-q}{b}(n-q)}, \text{ and} \tag{7}$$

$$m \le \frac{1}{1+\frac{b-q}{b}(n-1)+\left(\frac{q}{b}-\frac{n-q}{N-b+1}\right)(q-1)} \text{ if } b < N\text{-}n \text{ or}$$

$$m \ge \frac{1}{1+\frac{b-q}{b}(n-q)} \text{ if } b > N\text{-}n \tag{8}$$

The expected payoff of a player who contributes 0 is $\pi(0) = w_i + m\frac{n-q}{N-b}qs_i$ if $b < N$-n and $\pi(0) = w_i + mqs_i$ if $b > N$-n. If this player raises his contribution by 1, his payoff is $\pi(1) = w_i - 1 + m + mqs_i$. If the player matches the contributions of the other players, his payoff is $\pi(s_i) = w_i - s_i + ms_i + m\frac{b-q}{b+1}(n-1)s_i + m\frac{q+1}{b+1}(q-1)s_i$. The player could also increase his contribution by one above everybody else's if $s_i < \overline{w}$, so that he is in the highest group with probability one, resulting in a payoff of $\pi(s_i+1) = w_i - s_i - 1 + m + ms_i + m(n-1)s_i$. The conditions characterizing the pure strategy Nash equilibrium from this player's view point are described in (9) and (10)

If $b < N$-n then

$$m \le \frac{1}{1+\frac{N-b-n+q}{N-b}qs_i},$$

$$m \le \frac{1}{1+\frac{b-q}{b+1}(n-1)+\frac{q+1}{b+1}(q-1)-\frac{n-q}{N-b}q}, \text{ and}$$

$$m \le \frac{s_i+1}{1+(n-1)s_i-\frac{n-q}{N-b}qs_i} \text{ if } s_i < \overline{w} \qquad \textbf{(9)}$$

If $b > N\text{-}n$ then

$$m \le \frac{1}{1+\frac{b-q}{b+1}(n-1)+\frac{q+1}{b+1}(q-1)-q}, \text{ and}$$

$$m \le \frac{s_i+1}{1+(n-1)s_i-qs_i} \text{ if } s_i < \overline{w} \qquad \textbf{(10)}$$

<u>Existence of equilibria with positive contributions</u>

Inequalities (6) – (10) help identify the pure strategy Nash equilibria for a specific set of N, n, w_i within a specific MPCR m.[9] We examine MPCRs of 0.3 and 0.5, where $N = 12$, $n = 4$, and $w_i = 100$ for all i. Table 1 lists, for these particular cases, the equilibria that involve some positive contributions s_i*.[9] Since the equilibria are asymmetric and each of the symmetric participants contributes either s_i^* or s_k^*, there exist $\binom{N}{b}$ equilibria for each row of Table 1.

The following theorem shows the conditions that guarantee the existence of equilibria characterized by only a few players contributing nothing in the lowest group and everyone else contributing the highest possible amount $\overline{w}$.

[9] The equilibrium in which all contribute nothing (Observation 2) is omitted from the Table.

Theorem: If $m > \frac{1}{n}$ **(11)**, that is, is it Pareto optimal for everyone to contribute everything to the group account, and G > 1 **(12)**, then there exists at least one pure strategy Nash equilibrium in which *b* > (N– n)* players contribute $\overline{w}$ and the remaining $N - b^*$ players contribute nothing.

Proof: It is easy to see that from the viewpoint of every player contributing $\overline{w}$, $\pi_{\overline{w}}(y) < \pi_{\overline{w}}(0)$ for any y < $\overline{w}$ because strategy *y* will keep this player in the lowest group together with all the *0*-contributors. An equilibrium as described in the above theorem exists only if there is some *b* for which $\pi_{\overline{w}}(\overline{w}) \geq \pi_{\overline{w}}(0)$. We denote by *h(b)* the difference between the current expected payoff of a player contributing $\overline{w}$ and her expected payoff if she unilaterally switches to *0*. We have *h(b)* = $\pi_{\overline{w}}(\overline{w}) - \pi_{\overline{w}}(0) =$

$-\overline{w} + m\overline{w} + m\frac{N-n}{b}(N-b)\overline{w}$. The derivative $\frac{\partial h(b)}{\partial b} = -\frac{\overline{w}N(N-n)}{b^2} < 0$, hence *h(b)* is always decreasing, and reaches *0* at $b^*_{\overline{w}} = \frac{mN(N-n)}{m(N-n)+1-m}$ **(13)**. It follows that for every b $< b^*_{\overline{w}}$, $\pi_{\overline{w}}(\overline{w}) > \pi_{\overline{w}}(0)$.

Let us next look at the equilibrium configuration from the point of view of the players contributing zero. These players also face $\pi_0(y) < \pi_0(0)$ for any y < $\overline{w}$ because strategy *y* will keep such a player in the lowest group together with all the other *0*-contributors. An equilibrium as described in the theorem exists only if there is some *b* for which $\pi_0(\overline{w}) \leq \pi_0(0)$. Let us denote by *f(b)* the difference between the current expected payoff of the players contributing *0* and the player's expected payoff if such a player unilaterally switches to $\overline{w}$. In this case we have *f(b)*= $\pi_0(0)-\pi_0(\overline{w})=\overline{w}-m\frac{\overline{w}}{b+1}(N-n)(N-b)$. We see that

$\frac{\partial f(b)}{\partial b}=\frac{m\overline{w}(N-n)(N+1)}{(b+1)^2}>0$, so *f(b)* is always increasing, and reaches *0* at

$b_0^*=\frac{mN(N-n)-1}{m(N-n)+1}$ **(14)**. We conclude that for every b > b_0^*, $\pi_0(0)>\pi_0(\overline{w})$. Comparing

$b_{\overline{w}}^*$ and b_0^*, it can be seen that b_0^* < $b_{\overline{w}}^*$ since $b_{\overline{w}}^*$ has a larger numerator and a smaller denominator. Hence, there is always some *b* between b_0^* and $b_{\overline{w}}^*$ for which $\pi_{\overline{w}}(\overline{w})>\pi_{\overline{w}}(0)$ and $\pi_0(0)>\pi_0(\overline{w})$ because of the properties of the *h(.)* and *f(.)* functions discussed above.[10] It follows that there is always some *b* for which no player has an incentive to deviate from his strategy. To complete the proof it is sufficient to show that, under the conditions of the theorem:

(a) There is an *integer b* between b_0^* and $b_{\overline{w}}^*$ or b_0^* + 1 < $b_{\overline{w}}^*$.

(b) $b_0^*>N-n$

Using (13) and (14) we can show that (a) is equivalent to $m>\frac{1}{n+1}$. The latter is true because of (11). Using (14) we see that (b) is equivalent to

$$m>\frac{1}{n}\frac{n-1}{N-n} \quad \textbf{(15)}$$

It is easy to verify that (15) is also true because of (11) and as long as $n\leq\frac{N+1}{2}$, which is equivalent to (12) .

This completes the proof.

Note that the criteria for the existence of the equilibrium described in the Theorem are not very strict. As long as it is Pareto optimal for everyone to contribute everything to

[10] Since these are strict inequalities, there only exists some *b* between b_0^* and $b_{\overline{w}}^*$ for which the equilibrium is strict.

the public account and the population is divided in at least two groups, the MM has a pure strategy Nash equilibrium in which a large proportion of all individuals contribute the highest possible amount to the public account. This might be one of the reasons for the relatively frequent usage of this mechanism in practice. Another reason is the broad nature of the MM's team output.

II.B. The excludability of the group good in the MM

Extending the concept of excludability

By adding competitive sorting based on contributions to an otherwise standard VCM we also explore a more general conjecture about the effects of excludability on the ease of providing public goods. It is generally accepted that excludable group goods are more easily provided than nonexcludable ones, and that goods can be placed on a spectrum according to their excludability (Buchanan, 1965). However, there is an additional and often overlooked point to consider: what exactly are the criteria for exclusion? Are they under individual control, such as effort or are they entirely arbitrary?

We suggest expanding Buchanan's spectrum with a second axis representing to what extent the exclusion criteria are under individual control. The latter obviously is most important for efficiency since it determines to what extent individuals can be incentivized to work for the public good. Obviously, random assignment in the VCM is meant to model non-excludability - all participants have an equal chance of being in any group. However, with regard to its arbitrariness, disconnectedness from output, and lack of individual control, a lottery for group membership in an experiment is equivalent to the genetic lottery of gender or skin color which determines life-long strata assignment in non-meritocratic societies.

In Section II.A we found that with increased performance-related rather than arbitrary excludability **A)** quite inefficient equilibria still exist (See Table 1 and Observation 2), **B)** there are still no 100% efficient equilibria, and **C)** as long as the conditions in the Theorem are met, there always exists an equilibrium in which the resource allocation is close to Pareto optimal. The experimental results (Section V) show that this most efficient equilibrium is reliably selected by experimental subjects.

The location of the MM team output along Buchanan's spectrum

Various mechanisms have been proposed in the past for the provision of public goods. See Vickrey (1961), Clarke (1971), Groves (1973), Smith (1977), Walker (1981), and Varian (1994) for some of the most notable. Manageable versions of some of these mechanisms have been tested in the laboratory, but with mixed results (See, e.g. Scherr & Babb, 1975; Smith, 1977; Chen & Tang, 1998; Andreoni & Varian, 1999; Attiyeh, Franciosi & Isaac, 2000; Chen & Gazzale, 2005; Oprea, Smith & Winn, 2005) and these mechanisms have usually not been used in the field.[11] The MM in contrast has evolved in the field and, as discussed in Section I, has been implemented in diverse contemporary and even historical settings.

It matters for the practical applicability of the MM model that the team output in both the VCM and the MM need not be a pure public good in Samuelson's (1954) sense. Rather, the VCM's and the MM's group account covers a range near the public end of Buchanan's (1965) spectrum, not just an endpoint. This is because group size is fixed and every group member gets the same share of the group account. Any debate about the extent to which the group account is congestible, excludable, or rival is therefore unnecessary.[12] Further, the linear and commonly known monetary payoff functions of the VCM and MM

[11] To our knowledge the sole exception is a market-like mechanism used in a public good context, reported in Ferejohn and Noll (1976).

[12] Were group size variable (non-excludability), experimentally (hence, monetarily) modeling nonrival consumption of the joint output poses a challenge since the MPCR varies with group size unless g is also concomitantly varied; the latter however affects the attractiveness of the social optimum.

allow bypassing the issue of preference revelation that is central to traditional public goods mechanisms. The VCM's and MM's focus is thus shifted away from determining the optimal allocation and provision level and toward the act of free-riding itself. The group account in the VCM or MM can represent any joint output by a team, organization or society, ranging from a pure public good to a shared good that is divisible and/or rival, such as for example a pooled investment.

Since it covers a broad range of goods the MM model is applicable in a variety of contexts, as a social or organizational structure that increases efficiency or effectiveness.

II. C. The stability of the relatively efficient equilibria in the MM

MPCR-dependent risk and strategic uncertainty

It is well known that in a standard VCM the MPCR affects behavior even though, within the limits set by the social dilemma property of the game, it does not affect the equilibrium: the lower the MPCR, the faster the convergence toward non-contribution by all (See, e.g., Gunnthorsdottir, Houser & McCabe, 2007; Isaac & Walker, 1988; Isaac, Walker & Thomas, 1984). There are two possible reasons for this: First, the lower the MPCR the less of a difference there is between the efficient payoff when everybody contributes and the equilibrium payoff when nobody contributes. Second, the maximum a full contributor can lose is $(1-m)\ w_i$, while non-contribution guarantees a payoff of at least w_i. There is ample evidence, starting with Kahneman and Tversky's (1979) seminal paper, that people are sensitive to the risk of losses in relation to their original wealth level w_i . All these facts taken together mean that contributing, never an equilibrium strategy in the VCM, is even less attractive there the lower the MPCR. These principles hold essentially for the MM as well, but with additional twists.

Compared to the VCM, the MM involves additional strategic uncertainty. First, there is now a choice between equilibria; the MPCR determines their number and structure Second, in any equilibrium involving positive contributions a contributor's final payoff depends on the random process that solves the ties for group memberships inherent in all such equilibria. The probability of a contributor being in either a heterogeneous or a homogeneous group is determined by the MPCR-dependent parameter *b* (See Table 1, columns 1 and 2).

Another risk-related feature of the equilibria in Table 1 worth noting is that the expected payoff from contributing (column 5) is slightly lower than the payoff from free-riding (column 7), be the latter expected (if *b*=5) or even guaranteed (if *b*=9). Further, in all equilibria under MPCR= 0.5 the highest payoff a contributor could earn if she is assigned to a homogeneous group (right half of Column 4) equals a non-contributor's certain payoff (See columns 6 and 7). Under MPCR=0.3, if *b*=9, an equilibrium with positive contributions is even less favorable to a contributor: Even her highest possible payoff (column 4 right) is slightly lower than what a non-contributor has guaranteed (columns 6 and 7).[13]

If subjects are sensitive to the fact that the efficient payoff is lower under MPCR=0.3 than under MPCR=0.5, or are averse to loss relative to their original endowment level w_i (Kahneman & Tversky, 1979), or are responsive to how the (sometimes even certain) free-rider payoff in equilibrium compares to the expected cooperator payoff and its upper range, one could expect behavioral differences between MPCR=0.3 and MPCR=0.5. In particular, subjects might be more reluctant to contribute fully under MPCR=0.3, possibly settling for one of the equilibria with a low s_i (See Table 1, column 3).

---

[13] If *b*=5 then contributors and non-contributors alike face expected, rather than secure, payoffs. Again, non-contributor expected payoffs slightly exceed contributor expected payoffs. It can easily be verified however that movement away from any configuration listed in Table 1 is not stable.

Robustness to small deviations by individual players

While the relatively efficient equilibrium configurations in Table 1 may be susceptible to risk attitudes, they are quite robust to deviations by single players. In this sense the MM differs significantly from weakest link games or step-level public goods games, (discussed in the next section) where a deviation by a single player can prove quite disastrous to overall efficiency since it immediately drives everybody else's incentives toward a much less efficient equilibrium. In all configurations listed in Table 1, if a player reduces his contribution even by a small amount, he is placed in the lowest group with certainty. The remaining full contributors have an increased chance of being assigned to a homogeneous contributor group and have no incentive to change their strategy. The configuration is equally stable if a non-contributor deviates.

III. RELATED GAMES AND EXPERIMENTAL FINDINGS

If refined by the payoff dominance criterion (Harsanyi & Selten, 1988) the MM leads to unique predictions about aggregate behavior. The payoff dominance principle however is not the sole method of equilibrium selection and not entirely uncontested (See, e.g., Binmore, 1989; Aumann, 1988). It is therefore desirable to triangulate with an empirical test of equilibrium selection for specific games. Does the MM's contribution-based group assignment indeed induce participants to coordinate the most efficient equilibrium, asymmetric and counterintuitive as it is? We now proceed to briefly review the experimental literature on competitive group membership, and the tacit coordination of payoff dominant and asymmetric equilibria that would lead one to hypothesize such an outcome.

Exclusion and Competitive group membership

Recent empirical studies with the standard VCM as their benchmark show impressive efficiency gains if it is common information that group membership is competitively based on contributions. Cabrera, Fatas, Lacomba & Neugebauer's (2006) two-group experiment indicates that even very limited contribution-based mobility raises average contributions.[14] In an experiment by Cinyabuguma, Page and Putterman's (2005) there was greater mobility; subjects were informed about each others' historical contributions[15] and could permanently expel others, via a majority vote. Most relevant to the MM are the results of Page, Putterman & Unel (2006). Players were again informed about each others' historical contributions and ranked each other on their desirability as fellow group members. The ranking determined the composition of fixed-size groups. As in all these studies, there were substantial efficiency gains. Interestingly, endogenous decentralized ranking by the participants themselves accurately traced individuals' historical contribution. In real-world meritocratic systems ranking is frequently decentralized and endogenous as in Page et al.'s study. We note however that centralized ranking, as in the MM, is also common.[16]

Tacit Coordination

The MM requires two forms of tacit coordination: First, participants must coordinate one among multiple Pareto-ranked equilibria. Second, since most pure strategy equilibria including the most efficient one are asymmetric (Table 1), subjects must coordinate the equilibrium strategies in the correct proportions. Each of these coordination

[14]Croson, Fatas & Neugebauer (2006) apply a different form of limited exclusion. The lowest contributor is excluded from the group output in that round, rather than from the group, which maintains its composition over rounds. Hence, there is no contribution-based re-stratification. It is noteworthy that competition within a team for access to the group output, rather than competition across a mini-society as in the MM, also raises contributions to near-optimal levels.

[15] The inclusion of historical contributions in ranking systems, such as in Cinyabuguma et al. and Page et al. is a realistic assumption, as seen in the reliance on vitas, references, and other reputational mechanisms. However, it would significantly complicate any attempt an equilibrium analysis.

[16] With regard to promotion or skilled immigration, for example, ranking is by a central agent. On the other hand, endogenous stratification exists in labor markets, or in self-selected teams such as among co-authors.

challenges has been studied extensively on their own, in particular in market entry games (asymmetric equilibria), and weakest link games (multiple Pareto ranked equilibria), games substantially differ from the MM. They co-occur in step-level VCMs. We now briefly review each in turn.

Tacit coordination of asymmetric equilibria. In the most typical version of the market entry (ME) game (Selten & Guth, 1982; Gary-Bobo, 1990) each player decides whether or not to engage in an activity, such as entering a market. For not entering, the payoff is a low, positive constant; for entering, the payoff is potentially higher but decreases in the number of entrants. In the (Pareto deficient) equilibrium payoffs from entering or staying out are - somewhat depending on the granularity of the parameters - roughly equal. Relatively large groups of experimental subjects coordinate these asymmetric equilibria "without learning and communication" (Camerer & Fehr, 2006, p.50). See, e.g., Meyer, Van Huyck, Battalio & Saving 1992; Rapoport, 1995; Rapoport, Seale, Erev & Sundali, 1998; Sundali, Rapoport and Seale, 1995; Erev & Rapoport, 1998. Even though the equilibrium organizes aggregate behavior surprisingly well, individual level data are quite unsystematic, supporting neither pure nor mixed strategies (Rapoport, Seale & Winter, 2002; Seale & Rapoport, 2000; Erev & Rapoport, 1998; Rapoport, 1995; See also Duffy & Hopkins, 2005).

Multiple Pareto ranked equilibria. In a series of "weakest link" (henceforth, WL) games much replicated since, Van Huyck and colleagues let symmetric subjects simultaneously choose an integer. The higher the integer the higher the cost to the individual, and the higher the associated potential payoff. However, everyone's payoff is determined by the lowest integer chosen within the group. Hence, any contribution above this "weak link" is wasted. Any symmetric choice pattern is an equilibrium; the most efficient is where everyone chooses the highest possible number. Overall, there is mixed support in these games for the claim that a payoff dominant equilibrium is always focal (see, e.g., Van Huyck, Battalio & Beil, 1990, 1991; See also Ochs, 1995 for an overview; See Cooper, DeJong, Forsythe & Ross,1990, Brandts & Cooper, 2006; Weber, Camerer & Knez, 2004; Keser, Ehrhart & Berninghaus,1998 for replications).

A WL game differs from the MM in the strategic uncertainty associated with high contributions: In the former, choosing a high number is risky for everyone. A deviation downward by even a single "weak link" negatively affects everyone else's payoff. In the MM the payoff from a high group contribution is less uncertain since the game extends across groups but final payoffs are computed based on contributions within groups. Therefore, one or even several players' deviation often have little impact on a contributor's expected earnings and often have a positive, rather than a negative, effect (See Section II.C). [17]

Pareto-ranked asymmetric equilibria in a step-level VCM. In step-level VCMs (henceforth, SL-VCM) (Isaac, Schmitz & Walker, 1984) the group account only yields a payoff if joint contributions reach a specified level. Any configuration with aggregate contributions at that level is an equilibrium. Even though both are variations of the standard VCM, there are significant structural differences between a SL-VCM and the MM. Most notably again, the efficient equilibrium in the SL-VCM is much less stable than in the MM. Similar to WL games, in the SL-VCM a slight deviation by one contributor so that the required threshold is not reached drives everyone's incentives toward the equilibrium of non-contribution by all. [18] In fact, in the majority of instances, the SL-VCM

[17] Competition between groups with regard to the integer level chosen (Bornstein Gneezy & Nagel, 2002; Riechmann & Weimann (2004), or exclusion of the "weakest link" which effectively reduces risk (Fatas, Neugebauer & Perote, 2006) help facilitate coordination on a Pareto superior outcome.

[18] Another difference is that in an asymmetric equilibrium in the SL-VCM, the payoffs from its different strategies can vary greatly. In the MM by contrast, all expected, even though not necessarily final, payoffs are very similar across all strategies that are part of an asymmetric equilibrium. In that sense the MM resembles ME games where, in equilibrium, payoffs for different strategies are equal or close to equal.

is not very effective at maintaining high contributions.[19] The MM in contrast, as the experimental test described below shows, is very effective at raising efficiency.

IV. METHOD

Design and participants

The MM was examined under MPCR=0.5 and MPCR = 0.3 (see Table 1). Both MPCRs are commonly used in linear VCM experiments. Under each MPCR condition, there were four experimental sessions with twelve participants each, a total of 96 subjects. Subjects were undergraduates from George Mason University were recruited from the general student population for an experiment with payoffs contingent upon the decisions they and other participants made during the session. Each session lasted for about two hours.

Procedure

Each participant received a $7 show-up fee, and was privately paid her experimental earnings at the end of the experiment. Participants were seated at computer terminals, visually separated from others by blinders. At the beginning of each round, each subject received one hundred tokens to invest in either a private account, which returned one token for every token invested to that subject alone, or a group account, which returned tokens at the specified MPCR to everyone in his group including himself. For example, when the MPCR was 0.5, each token contributed to the group account returned 0.5 tokens to each person in the group. A new period began after all of the subjects indicated that they

---

Related, in the SL-VCM subjects who apply the same strategy receive the same payoff. This is not the case in the MM because of the random solving of ties, which always occurs in equilibrium (Table 1).

[19] Its effectiveness depends somewhat on how high the threshold is. The higher the threshold, the riskier a contribution is. If the risk associated with wasted contributions is removed, contributions often rise even though there is also evidence to the contrary (see, e.g., Dawes et al., 1986).

were ready. [20]

<u>*Group assignment*</u>. In each round the twelve participants decided simultaneously how to divide their endowment between the group account and their respective individual accounts. After all subjects had made their contribution decisions they were separated in three groups of four: The four highest investors to the group account were put into one group, the fifth through the eighth highest investors into another group and the four lowest investors into a third group, with ties broken at random. After grouping, subjects' earnings were calculated based on the group to which they had been assigned. Note that group assignment depended only on the subjects' *current* contributions, not on contributions in previous rounds. Subjects were regrouped according to these criteria at each of the 80 decision rounds. Appendix A contains the written instructions.

<u>*End-of-round feedback*</u>. After each round, an information screen showed a subject's own private and public investment in that round, the total investment made by the group she belonged to, and her total earnings. The screen also contained an ordered series of the group account contributions by all participants, with a subject's own contribution highlighted so that she could see her relative standing. This ordered series was visually split into three groups of four, which further underscored that participants had been grouped according to their contributions, and that any ties had been broken at random. .

[20] The exchange rate between tokens and US Dollars was 1000:1. In session 05-1 the exchange rate was 880:1. Data from this session were not different from the data of the other MPCR=0.5 sessions. This session was therefore included in the data set and in the aggregate analyses.

V. RESULTS

Result 1

The MM substantially and reliably increases efficiency compared to a standard VCM.

The solid lines in Figure 1 display mean contributions per MPCR and per round. Contributions are high and stable over all 80 rounds. Compare this to the regular VCM's mean contributions, which start at about half of the endowment and decline toward the vicinity of zero within about ten rounds (Ledyard, 1995; Davis & Holt, 1993).

Result 2

Observed mean contributions correspond to mean contributions in the Pareto dominant equilibrium.

The broken lines in Figure 1 represent the predicted mean contributions in the Pareto dominant equilibrium. Observed mean contributions per MPCR (solid lines) closely and steadily trace the predicted values. Mean contributions over all 80 rounds are 70 tokens for MPCR=0.3 (75 if the Pareto dominant equilibrium is adhered to without error) and 84 tokens under MPCR=0.5 (83.3 in the Pareto dominant equilibrium). [21] This patterns also emerges in the single sessions where the means are 65.2, 72.2, 71.8 and 72.3 for MPCR=0.3, and 86.1, 83.1, 81.3 and 84.9 for MPCR=0.5. The paths of single session over trials (Figure 2) resembles their aggregate pattern shown in Figure 1.

Result 3

Strategies that are part of the Pareto dominant equilibrium are predominantly selected.

The most efficient pure strategy equilibrium in the MM is extremely asymmetric since it consists of the two corner strategies from among a set of 101 strategies. Figure 3

[21] Mann-Whitney-Wilcoxon tests (See, e.g., Siegel & Castellan, 1988) with each session mean as one observation reject the null hypotheses that the mean contributions are the same across MPCRs ($w=10$, $p < 0.014$)

displays the percentage in which available choices occurred over all trials, per MPCR. In both MPCR conditions, subjects concentrated on the two strategies that are part of the payoff dominant equilibrium. Choices closely neighboring them are also somewhat more frequent. In light of the pattern displayed in Figure 3, in the analysis that follows choices ≥98 are classified as full contributions, and choices ≤ 2 as noncontribution. [22] With this classification, 86 % of choices under MPCR 0.5, and 66% of choices under MPCR=0.3 fall under one of the two equilibrium strategies. [23] Result 5 below addresses this MPCR-related difference in percentages. There is no indication of attempts at any of the other less efficient equilibria involving low positive contributions (See Table 1, column 3).

<u>Result 4</u>

The proportions in which equilibrium strategies were selected are very close to those of the payoff dominant equilibrium.

In the payoff dominant equilibrium 10/12 of subjects (83.3%) make a full contribution under MPCR=0.5, and 9/12 under MPCR=0.3, while the remainder contributes nothing (See Table 1, columns 2, 3 and 8, shaded cells). Figure 4 displays, by MPCR and per round, the observed percentage of zero contributions and full contributions, and their respective proportions in the Pareto dominant equilibrium. Within a few trials subjects reach close-to-equilibrium proportions. Figure 5 confirms this aggregate pattern for every single session even though the pattern is slightly less pronounced under MPCR-0.3, particularly in session 3-1.[24]

[22] This is in accordance with both the prominence hypothesis (Selten, 1997) that people tend to make their choices in multiples of five, and the argument about neighboring strategies by Erev and Roth (1998). As can be inferred from Figure 3, this classification only minimally changes the analysis since choices closely neighboring the exact equilibrium strategies are relatively few.

[23] The respective exact counts are 83% and 56%.

[24] One-sample Kolmgorov-Smirnov tests (See, e.g., Siegel and Castellan, 1988) of the null hypothesis that the data come from a distribution exactly as specified in the most efficient equilibrium failed to rejected the null hypothesis at p=0.001 for sessions 05-1 and 05-2. Note that these are very stringent tests since behavior under a choice among 101 strategies is tested against a null hypothesis distribution that only allows for two strategies in specific proportions.

Result 5

There are indications of behavioral MPCR effects.

Figures 1- 5 show that aggregate contributions vary by MPCR as theoretically expected if the most efficient equilibrium is realized in both MPCR conditions. While behavior under both MPCR conditions is close to the respective Pareto dominant equilibrium, it appears somewhat closer under MPCR=0.5 than under MPCR=0.3. Under MPCR=0.5 the absolute frequencies of zero and full contributions over all 80 rounds are respectively 7 and 8 absolute percentage points lower than expected, but for MPCR=0.3 this difference is 9% and 26% (see also Figures 4 and 5). A one-tailed nonparametric Mann-Whitney-Wilcoxon test (See, e.g., Siegel and Castellan, 1988) with each session as an observation borderline rejects ($p \leq 0.056$) the null hypothesis that the frequency of intermediate strategies, (that is, strategies that are not part of the equilibrium configuration) under MPCR=0.5 is equal to or larger than the frequency under MPCR=0.3, in favor of the alternate hypothesis (tentatively developed in Section II.B) that intermediate strategies are more frequent under MPCR=0.3. However, a Kolmogorov-Smirnov test [25] fails to reject the null hypothesis that the shape of distributions of intermediate strategies differ by MPCR. Hence, their lower MPCR did not lead MPCR=0.3 subjects to systematically attempt any of the equilibria with lower positive contributions (Listed in Table 1, column 3).[26] Figure 3 confirms that if subjects meant to somehow hedge their bets under MPCR=0.3, their hedging strategies covered the entire strategy space.

---

[25] For this test choices were bundled into multiples of five, based on the pattern displayed in Figure 3. For example, choices of 3, 4, 6 and 7 were recoded as "5".

[26] In fact the mean of the intermediate contributions is higher under MPCR= 0.3 (59/100) than under MPCR=0.5 (48/100) but this difference is not significant (Mann-Whitney-Wilcoxon test with the mean of intermediate strategies per session as one unit of observation, W=13, $p \leq 0.20$).

Result 6

Individual strategies are unsystematic.

Individual choices over trials can be viewed at http://www.agsm.edu.au/~bobm/data**.** As mentioned in Section II.A, for each row in Table 1 there are actually $\binom{N}{b}$ asymmetric equilibria, with various players taking one of two roles, either contributing or not contributing. As Ochs (1999, p.143) states, once a profile of mutual best responses is realized, there is reason to expect that this stable pattern is repeated. While the payoff dominant equilibrium organizes aggregate behavior per round, individual choice paths over trials are diverse and hard to account for. Some subjects stick with one (mostly equilibrium) strategy, others alternate between the two equilibrium strategies or between equilibrium strategies and intermediate choices, in varying proportions. There is no evidence that individual strategies stabilize with experience. In this regard, the data resemble the well-documented pattern in ME games where aggregate behavior is also well captured by the equilibrium while individual strategies are hard to account for. [27]

There is however one noteworthy regularity: In the standard VCM and some of its modifications in which subjects are sorted based on contributions but unbeknownst to them, stable contributor types have been identified. For example, some contribute as long as others do likewise, while so-called free-riders quite consistently contribute nothing (See, e.g., Gunnthorsdottir, Houser & McCabe, 2007; Ones & Putterman, 2006; Fischbacher, Gächter & Fehr, 2001; Keser & Van Winden, 2000; Kurzban & Houser, 2001; 2005). In the MM however, even though its asymmetric equilibria require behavioral heterogeneity including free-riding by a proportion of participants, there are hardly any stable free-riders.

[27] 31% of subjects in MPCR=0.5 made a full contribution in ≥ 70 of the 80 trials. In MPCR=0.3, 21% subjects did.

If those who contributed ≤ 2 in ≥ 50% of all trials are classified as non-contributors, there were only 6/96 such subjects, all in MPCR=0.3. [28]

VI. DISCUSSION

We have shown that a Meritocracy that stratifies participants according to their contribution to the group good is an effective mechanism to overcome the free-rider problem. A simple adjustment to the excludability of the group good, making strata membership individually controllable rather than arbitrary, changes the equilibrium structure of a standard VCM and vastly improves efficiency. In society people do in fact contribute to joint output, broadly defined, and we have reviewed some contemporary and historical examples that can be accounted for by our model. Since the nature of the team output covered by the model is broad, and equilibrium requirement for a close-to Pareto optimal solution not very strict (see Theorem Section II.A.) Meritocracy Mechanism is applicable to a wide variety of settings.

In our theoretical analysis we have extended a standard group-level analysis typical for the VCM into an analysis of a broadly defined social network in which members compete for inclusion in its various strata that vary in desirability. We believe that we have, at the same time, given some indications to what could explain prior empirical results that show impressive efficiency gains in otherwise standard VCMs if group membership becomes competitively based on contributions.

The experimental findings in the present study underscore the predictive and descriptive power of even quite complex Nash equilibria on the aggregate level, a phenomenon Kahneman (1988, p.12) termed “magical”. The Meritocracy Mechanism is particularly demanding on participants with regard to tacit coordination. There is a rich

---

[28] They contributed ≤ 2 in 75, 65, 54, 43, 43 and 40 trials, respectively.

strategy set and multiple Pareto-ranked equilibria, which are complex and counterintuitive. Somewhat surprisingly maybe, this is not a problem with regard to subject behavior. It is unlikely that participants in a Meritocracy Mechanism are able to grasp, or even roughly guess, its complex equilibria. Yet the most efficient equilibrium was reliably coordinated.[29]

Our results underscore the merits of meritocracies above and beyond the obvious: In addition to its other well-recognized benefits, a meritocracy increases a social unit's efficiency because it substantially reduces free-riding. There is less of an incentive to contribute if social stratification is by arbitrary privilege. If, however, an individual's contribution, a variable that is under individual control determines her group membership, there is an obvious incentive to do one's best. The empirical confirmation that the most efficient equilibrium is easily coordinated in an MM setting indicates that humans respond with ease to this kind of incentive structure, a fact also borne out by observing the diverse field settings in which the Mechanism has been implemented.

Criticisms and extensions

This paper has focused on the effectiveness of a new mechanism at the aggregate level. The workings of he MM on the individual level need to be examined in depth, such as individual decision strategies[30] and, possibly, an MPCR-related impact of loss aversion. On the aggregate level, we recognize that while strata size is often fixed it isn't always. Hence an extension where group size is endogenous and players are grouped based on whether their contributions are above or below certain thresholds would be appropriate.

Yet another important question is the potential effect of unequal endowments on the MM system. In the basic model introduced here this issue is bypassed since all participants

[29] Other somewhat structurally related games described in Section III are much simpler from a subject's viewpoint; their strategy space is often more restricted (WL games and in particular, ME games with binary strategy space), and their pure strategy equilibria are much more intuitive (ME, WL, and SL-VCM games all fall into the latter category).

[30] Analysis of individual strategies should into account the fact that ties are broken at random, which means that payoffs for the same strategy can vary between trials.

have equal endowments. The next step is to examine how sensitive the model is to inequities. Most communities provide some insurance and aid that raises the payoff of those less able to contribute, e.g., charities or unemployment benefits. Such equalizing practices could also be included into an MM model with unequal endowments, their extent varied, and the effects examined.

Finally, we recognize that a pure meritocracy in its simplest form may not always be optimal for a social unit, and not only because large payoff differentials could reduce social cohesion but also because individual contributions can be multidimensional. For example, in organizational hiring, in addition to direct output, there is the question of employees' cultural fit, and in some cases involving universities or nations, there is long-term strategic value in diversity. However, such factors could also be included in a model of a member's current and prospective contributions.

REFERENCES

Andreoni, James.1995. "Cooperation in public-goods experiments: Kindness or confusion?" *American Economic Review,* 85: 891-904.

Andreoni, James, and Hal Varian. 1999. "Preplay Contracting in the Prisoner's Dilemma." *Proceedings of the National Academy of Science* 96(10): 933, (10) 938.

Attiyeh, Greg, Robert Franciosi and R. Mark Isaac. 2000. "Experiments with the Pivot Process for Providing Public Goods". *Public Choice,* 102: 95-114.

Aumann, Robert. 1988**.** Foreword to *A General Theory Of Equilibrium Selection In Games,* by John Harsanyi and Reinhard Selten. Cambridge, MASS: MIT press.

Binmore, Ken. 1989. "A general theory of equilibrium selection in games." *Journal of Economic Literature*, 27: 1171-1173.

Bornstein, Gary, Uri Gneezy, and Rosemarie Nagel. 2002. The effect of intergroup competition on intragroup coordination: An experimental study." *Games and Economic Behavior*, 41: 1-25.

Brandts, Jordi, and David Cooper. 2006. "A Change Would Do You Good: An Experimental Study On How To Overcome Coordination Failures In Organizations." *American Economic Review,* 96, 669-693.

Buchanan, James M. 1965. "An Economic Theory of Clubs." *Economica*, 32(125): 1-14.

Cabrera, Susana, Enrique Fatas, Juan A. Lacomba, and Tibor Neugebauer. 2006. *Vertically Splitting a Firm – Promotion and Relegation in a Team Production Experimen*t. University of Valencia Working Paper.

Camerer, Colin, and Ernst Fehr. 2006. "When Does 'Economic Man' Dominate Social Behavior?" *Science*: 311(6): 47-52.

Chen, Yan, and Fang-Fang Tang. 1998. "Learning and Incentive Compatible Mechanisms for Public Goods Provision: An Experimental Study**."** *Journal of Political Economy,* 106: 633-662.

Chen, Yan, and Robert Gazzale. 2005. "When Does Learning in Games Generate Convergence to Nash Equilibria? The Role of Supermodularity in an Experimental Setting," *American Economic Review,* 94: 1505-1535.

Clarke, Edward H. 1971. "Multipart Pricing of Public Goods." *Public Choice,* 11: 17-33.

Cooper, Russell W., Douglas DeJong, Robert Forsythe, and Thomas Ross. 1990. Selection criteria in coordination games: Some experimental results. *American Economic Review,* 80: 218-33.

Croson, Rachel, Enrique Fatás, and & Tibor Neugebauer. 2007. "*Excludability and Contribution: A Laboratory Study in Team Production."* Working Paper. Wharton.

Cinyabuguma, Matthias, Talbot Page, and L. Putterman. 2005. "Cooperation under the threat of expulsion in a public goods experiment." *Journal of Public Economics,* 89: 1421–1435.

Davis, Douglas D., and Charles A Holt. 1993. *Experimental Economics*. Princeton: Princeton University Press.

Duffy, John and Ed Hopkins. 2005. Learning, Information, And Sorting In Market Entry Games: Theory And Evidence. *Games and Economic Behavior,* 51: 31–62.

Erev, Ido, and Alvin Roth. 1998. "Predicting how people play games: Reinforcement learning and experimental games with unique, mixed strategy equilibria.' *American Economic Review,* 88: 848-881.

Erev, Ido, and Amnon Rapoport. 1998. "Coordination, 'Magic' and Reinforcement Learning in a Market Entry Game." *Games and Economic Behavior,* 23: 146-175.

Estes, William K..1964. “Probability Learning.” *Categories of Human Learning*, ed. Arthur W. Melton. New York: Academic Press.

Fatas, E., Tibor Neugebauer, and J. Perote. 2006. “Within-Team Competition in the Minimum Effort Coordination Game.” *Pacific Economic Review,* 11(2): 247-266.

Ferejohn, John, and Roger Noll. 1976. "An Experimental Market for Public Goods: The PBS Program Cooperative." A*merican Economic Review Papers and Proceedings*: 267-273.

Fischbacher, Urs, Simon Gächter, and Ernst Fehr. 2001. Are People Conditionally Cooperative? Evidence from A Public Goods Experiment. *Economics Letters,* 71, 397-404.

Gary-Bobo, Robert J. 1990. "On the Existence of Equilibrium Points in a Class of Asymmetric Market Entry Games.” *Games and Economic Behavior,* 2(2): 239-246.

Groves, Theodore. 1973. "Incentives in Teams." *Econometrica,* 41: 617-33.

Gunnthorsdottir, Anna, Daniel Houser and Kevin. McCabe. 2007. “Disposition, History, and Contributions in Public Goods Experiments.” *Journal of Economic Behavior and Organization*, 62 (2): 304-315.

Harsanyi, John, and Reinhard Selten. 1988. *A General Theory Of Equilibrium Selection In Games.* Cambridge, Mass.: MIT Press.

Isaac, Mark R. and James M. Walker. 1988. “Group Size Effects in Public Goods Provision: The Voluntary contributions Mechanism.” *Quarterly Journal of Economics,* 103(1): 179-99.

Isaac, Mark R., James Walker, and Susan Thomas. 1994. “Divergent Evidence on Free Riding: An Experimental Examination of Some Possible Explanations.” *Public Choice* 43: 113-149.

Isaac, Mark R., Kenneth McCue, and Charles R. Plott .1985. “Public Goods Provision in an Experimental Environment”, *Journal of Public Economics,* 26: 51-74.

Kahneman, Daniel. 1988. "Experimental Economics: A Psychological Perspective." In *Bounded Rational Behavior in Experimental Games and Markets,* ed. Reinhard Tietz, Wulf Albers and Reinhard Selten. Berlin: Springer-Verlag. 11-18.

Kahneman, Daniel, and Amos Tversky. 1979. “Prospect theory: An analysis of decisions under risk.” *Econometrica*, 47: 313-327.

Karabel, Jerome. 2005. The Chosen: *The Hidden History of Admission and Exclusion at Harvard, Yale, and Princeton.* Boston, MA: Houghton-Mifflin.

Keser, Claudia, and Frans Van Winden, 2000. “Conditional cooperation and the voluntary contribution to public goods.” *Scandinavian Journal of Economics*, 102: 23-39.

Keser, Claudia, Karl-Martin Ehrhart, and Siegfried Berninghaus. 1998. “Coordination and local interaction: Experimental Evidence.” *Econonomics Letters,* 58: 269–275.

Kurzban, Robert, and Daniel Houser. 2005. “An experimental investigation of cooperative types in human groups: A complement to evolutionary theory and simulation.” *Proceedings of the National Academy of Sciences*,102:1803-1807.

Kurzban, Robert, and Daniel Houser. 2001. Individual differences and cooperation in a circular public goods game. *European Journal of Personality,* 15: S37-S52.

Ledyard, John O. 1995. “Public goods: A survey of experimental research.” In *Handbook of Experimental Economics,* ed. John Kagel and Alvin E. Roth, 111-194. Princeton, NJ: Princeton University Press.

Meyer, Donald, John Van Huyck, Raymond Battalio, and Thomas R. Saving. 1992. “History's role in coordinating decentralized allocation decisions: Laboratory

Evidence on Repeated Binary Allocation Games." *Journal of Political Economy,* 100: 292-316.

Ochs, Jack. 1995. "Coordination Problems." In *Handbook of Experimental Economics*, ed. John Kagel and Alvin Roth, 195-252. Princeton University Press.

Ochs, Jack. 1999. "Coordination in Market Entry Games." In *Games and Human Behavior: Essays in Honor of Amnon Rapoport*, ed. David Budescu, Ido Erev, and Rami Zwick, 143-172. Mahwah, NJ: Erlbaum.

O'Neill, B. 1987. "Nonmetric Test of the Minimax Theory of Two-Person Zerosum Games". *Proc. Nat. Acad. Sci,* 84: 2106-2109.

Ones, Unel, and Louis Putterman. 2006. "The Ecology of Collective Action: A Public Goods and Sanctions Experiment with Controlled Group Formation." *Journal of Economic Behavior and Organization*.

Oprea, Ryan, Vernon Smith, and Abel Winn. 2005. *A Compensation Election for Binary Social Choice.* Interdisciplinary Center for Economic Science, George Mason University, Arlington, VA., Working Paper.

Page, Talbot, L. Putterman, and B. Unel. 2006. "Voluntary Association in Public Goods Experiments: Reciprocity, Mimicry, and Efficiency." *Economic Journal,* 115: 1032–1053.

Rapoport, Amnon. 1995. "Individual Strategies in a Market-Entry Game." *Group Decision and Negotiation,* 4: 117-133.

Rapoport, Amnon, and Richard Boebel. 1992. "Mixed Strategies In Strictly Competitive Games: A Further Test Of The Minimax Hypothesis." *Games and Economic Behavior,* 4: 261-283.

Rapoport, Amnon, and David V. Budescu. 1997. "Randomization In Individual Choice Behavior." *Psychological Review,* 104: 603-618.

Rapoport, Amnon, Darryl Seale, and Eyal Winter. 2002. “Coordination and learning behavior in large groups with asymmetric players.” *Games and Economic Behavior,* 39: 111-136.

Rapoport, Amnon, Darryl Seale, Ido Erev, and James Sundali. 1998. “Equilibrium play in large group market entry games.” *Management Science,* 44(1): 119-141.

Riechmann, T. and Weimann, J. 2004. *Competition as a Coordination Device*. FEMM Working Paper Series No. 04014, Universität Magdeburg.

Samuelson, Paul. 1954. “The Pure Theory of Public Expenditure.” *Review of Economics and Statistics,* 36(4): 387-389.

Schelling, Thomas. 1971. “Dynamic Models of Segregation.” *Journal of Mathematical Sociology,* 1:143-186.

Scherr, Bruce A. and Emerson Babb. 1975. "Pricing Public Goods: An Experiment with Two Proposed Pricing Systems," *Public Choice,* 35-48.

Seale, Darryl A., and Amnon Rapoport. 2000. “Elicitation of strategy profiles in large-group coordination games.” *Experimental Economics*, 3: 153-179.

Selten, Reinhard, and Werner Guth. 1982. "Equilibrium Point Selection in a Class of Market Entry Games." *Games, Economic Dynamics, and Time Series Analysis: A Symposium in Memoriam Oskar Morgenstern,* ed. Manfred Deistler, Erhard Fürst, and Gerhard Schwödiauer, 101-116. Vienna: Physica.

Selten, Reinhard.1997. “Descriptive Approaches To Cooperation.” In *Cooperation: Game theoretic approaches*, ed. Sergiu Hart and Andreu Mas-Colell, 289-326. Heidelberg: Springer.

Siegel, Sydney, and John Castellan Jr.. 1988. “*Nonparametric Statistics for the Behavioral Sciences, 2nd Edition.* London: McGraw-Hill.

Smith, Vernon. 1977. "The Principle of Unanimity and Voluntary Consent in Social

Choice," *Journal of Political Economy*, 85(6): 1125-1140.

Sundali, James, Amnon Rapoport, and Darryl Seale. 1995. "Coordination in Market Entry Games with Symmetric Players." *Organizational Behavior and. Human Decision Processes,* 64: 203-218.

Van Huyck, John, Raymond Battalio, and Richard O. Beil. 1990. "Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure." *American Economic Review,* 80: 234-248.

Van Huyck, John, Raymond Battalio, and Richard O. Beil. 1991. "Strategic uncertainty, equilibrium selection principles, and coordination failure in average opinion games." *Quarterly Journal of Economics,* 106: 885-911.

Varian, Hal. 1994. "A Solution to the Problem of Externalities When Agents are Well-Informed," *American Economic Review,* 84: 1278-1293.

Vickrey, William. 1961**.** "Counterspeculation, Auctions and Competitive Sealed Tenders." *Journal of Finance*, 8-37.

Walker, Mark. 1981. A Simple Incentive Compatible Scheme for Attaining Lindahl Allocations." *Econometrica,* 49: 65-71.

Walker, Mark, and John Wooders. 2001."Minimax Play at Wimbledon." *American Economic Review,* 91(5): 1521-1538.

APPENDIX A

Instructions

This is an experiment in the economics of group decision-making. You have already earned $7.00 for showing up at the appointed time. If you follow the instructions closely and make decisions carefully, you will make a substantial amount of money in addition to your show-up fee.

There will be many decision-making periods. In each period, you are given an endowment of 100 tokens. You need to decide how to divide these tokens between two accounts: a **private** account and a **group** account.

Each token you place in the **private** account generates a cash return to you (and to you alone) of 1 cent.

Tokens that group members invest in the **group** account will be added together to form the group investment. The group investment generates a cash return of 2 cents per token. These earnings are then divided equally between group members. Your group has 4 members (including yourself).

Returns from the group investment are illustrated in the table below. The left column lists various amounts of group investment; the right column contains the corresponding personal earnings for each group member.

Returns from the Group Investment

Total investment by your group	*Return to each group member (From group investment)*
0	**0**
20	**10**
40	**20**
60	**30**
100	**50**
150	**75**
200	**100**
300	**150**
400	**200**

Example:
Assume that, in a specific period, your endowment is 100 tokens. Assume further that you decide to contribute 50 tokens to your private account and 50 tokens to the group account. The other group members together contribute an additional 250 tokens to their group accounts. That makes the group investment 300 tokens, which generates 600 cents (300 * 2 = 600). The 600 cents are then split equally among the 4 group members. Therefore, each group members earns 150 cents from the group investment (600/4=150). In addition to

earnings from the group account, each member gets 1 cent for every token invested in his/her private account. As you invested 50 tokens in the private account, your total profit in this period is 150 + 50 = 200 cents.

Each period proceeds as follows:
First, decide on the number of tokens to place in the private and in the group account, respectively. Use the mouse to move your cursor to the box labeled “Private Account”. To make your private investment, click on the box and enter the number of tokens you wish to allocate to this account. Do likewise for the box labeled “Group Account” Entries in the two boxes must sum to your endowment. To submit your investment click on the “Submit” button. You will then wait until everyone else has submitted his or her investment decision.

Second, once everyone has submitted his or her investment decision, you will be assigned to a group with 4 members (including yourself). **This assignment will proceed in the following manner:** participants' contributions to the group account will first be ordered from the highest to the lowest. Then the four highest contributors will be grouped together. Participants whose contributions ranked from 5-8 will form another group. Finally, the four lowest contributors will form the third group. Any ties that may occur will be broken at random. Experimental earnings will be computed *after* you have been assigned to your group. Thus, your contribution to the group account in a specific round affects which group you are assigned to in that round.

Third, you will receive a message with your experimental earnings for the period. This information will also appear in your Record Sheet at the bottom of the screen. The record sheet will also show the group account contributions by all participants in the experiment, including yours, in ascending order. Your contribution will be highlighted.

A new period will begin after everyone has acknowledged his or her earnings message.

After the last period, you will receive a message with your total experimental earnings (sum of earnings in each period).

This is the end of the instructions.

Table 1

Structure of equilibria with nonzero contributions for *N*=12, *n*=4, w_i = 100, and MPCR=0.3 or MPCR=0.5.

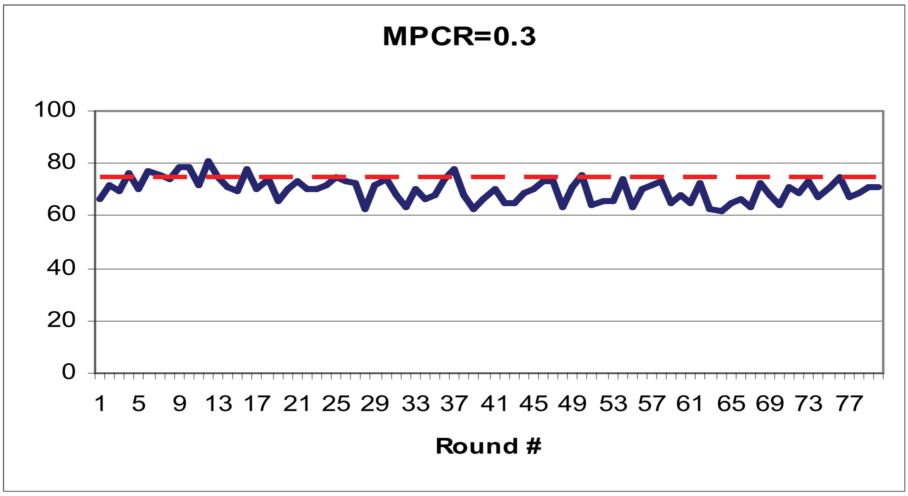
1	2	3	4		5	6		7	8
MPCR	b^1	$s_i{}^{*\,2}$	**Possible contributor payoffs**		**Expected contributor payoff**	**Possible non-contributor payoffs**		**Expected non-contributor payoff**	**Efficiency (percent)**
			Low	**High**		**Low**	**High**		
0.3	5	1	99.3	100.2	100.02	100	100.3	100.1	0.4
		2	98.6	100.4	100.04	100	100.6	100.3	0.8
		3	97.9	100.6	100.06	100	100.9	100.4	1.3
	9	1	99.3	100.2	100.1	n/a		100.3	0.7
		2	98.6	100.4	100.2	n/a		100.6	1.5
		3	97.9	100.6	100.3	n/a		100.9	2.3
		4	97.2	100.8	100.4	n/a		101.2	3.0
		5	96.5	101.0	100.5	n/a		101.5	3.8
		6	95.8	101.2	100.6	n/a		101.8	4.5
		7	95.1	101.4	100.7	n/a		102.1	5.3
		100	**30.0**	**120.0**	**110.0**	**n/a**		**130.0**	**75.0**
0.5	10	1	100.0	101.0	100.8	n/a		101.0	0.7
		2	100.0	102.0	101.6	n/a		102.0	1.5
		100	**100.0**	**200.0**	**180.8**	**n/a**		**200.0**	**83.3**

[1] The number of players out of twelve who make a nonzero contribution. The remaining 12-*b* players contribute zero.
[2] The amount of the nonzero equilibrium contribution (out of 100 tokens possible).

NOTE:
The pure strategy equilibrium of non-contribution by all (See Section II.A, Observation 2) , which exists in all MPCR conditions, has been omitted from this table.

Figure 1

Observed mean group investment per round, compared to mean group investment in the Pareto dominant equilibrium, per MPCR.



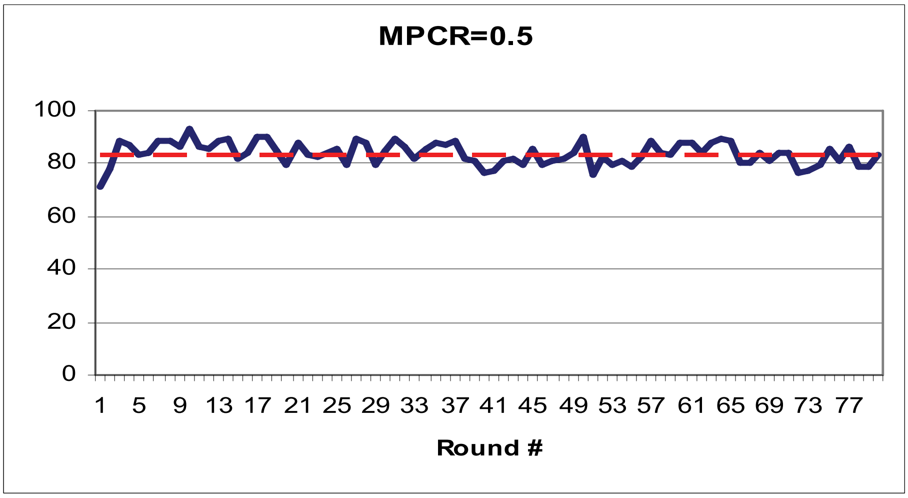
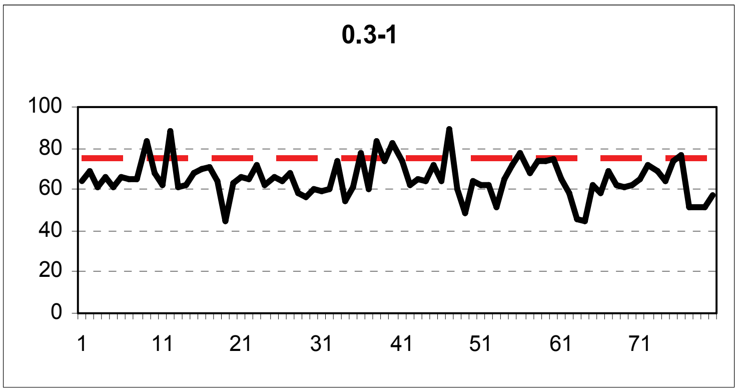
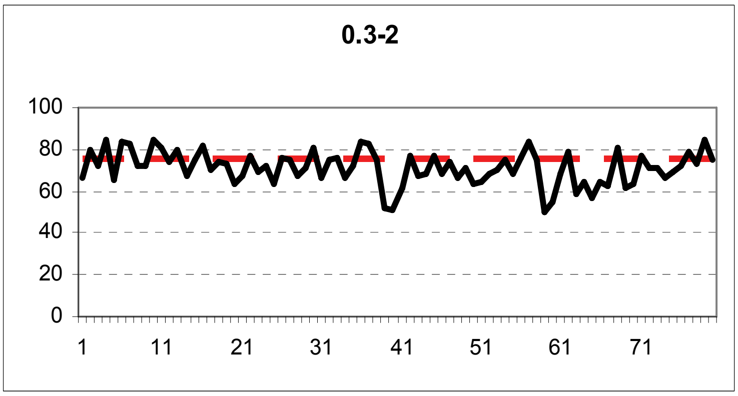
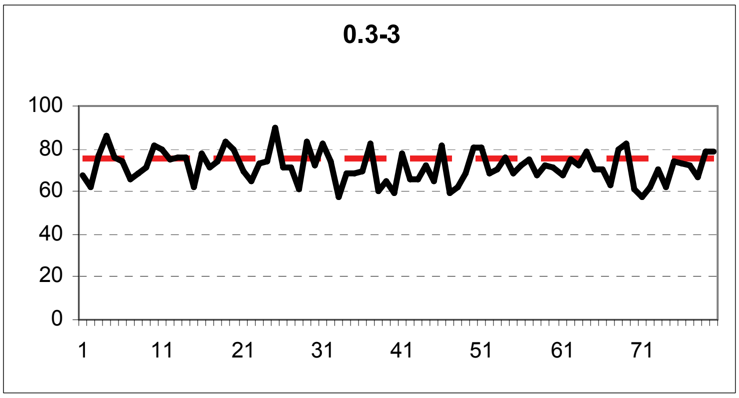


Figure 2A

Equilibrium and mean contributions per round, per session, MPCR=0.3







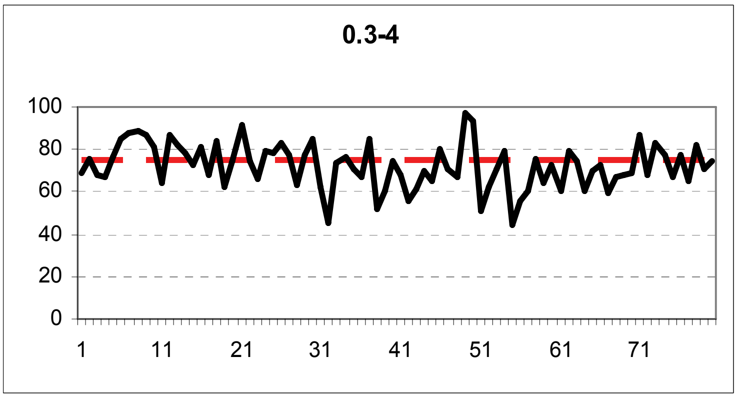


Figure 2B

Equilibrium and mean contributions per round, per session, MPCR=0.5

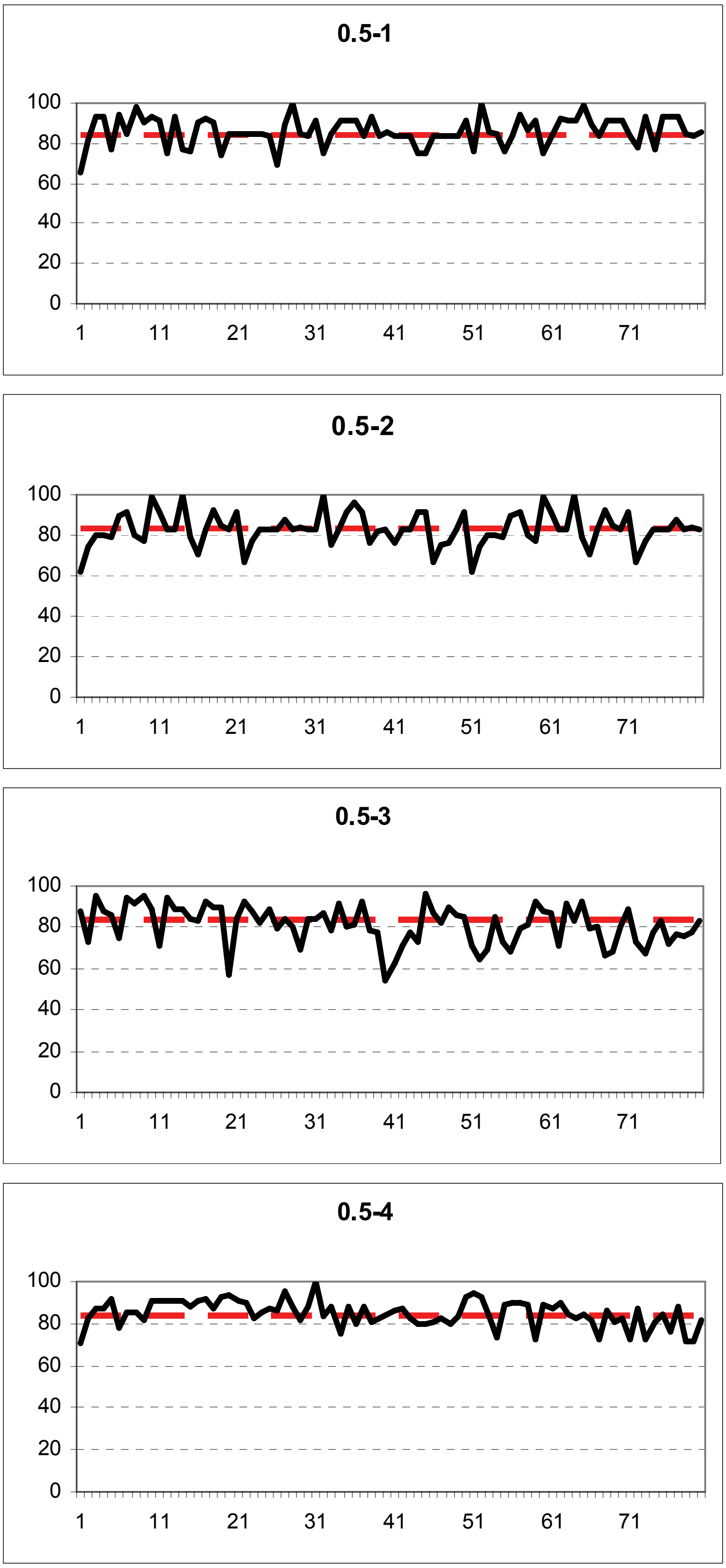
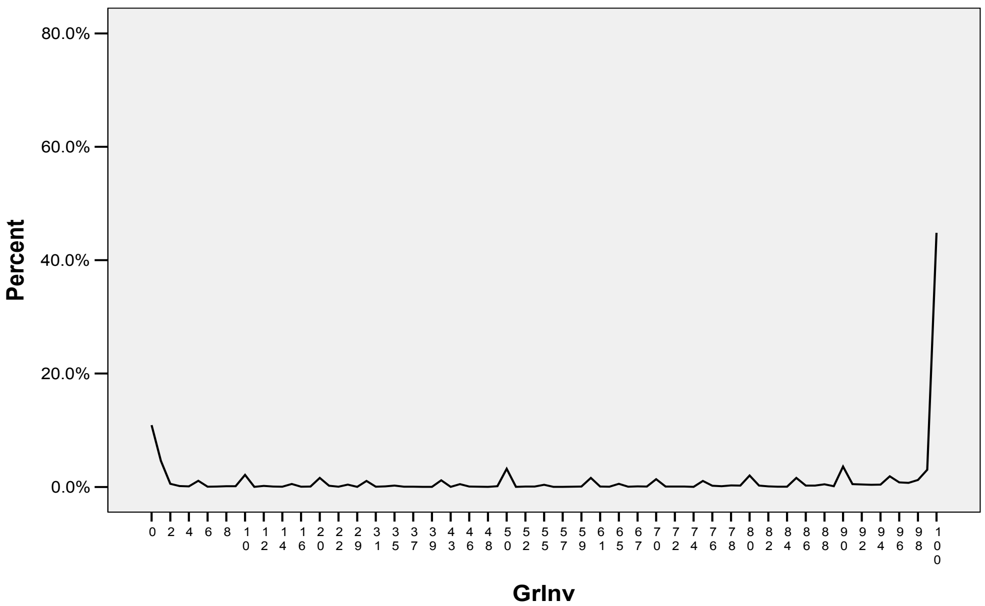


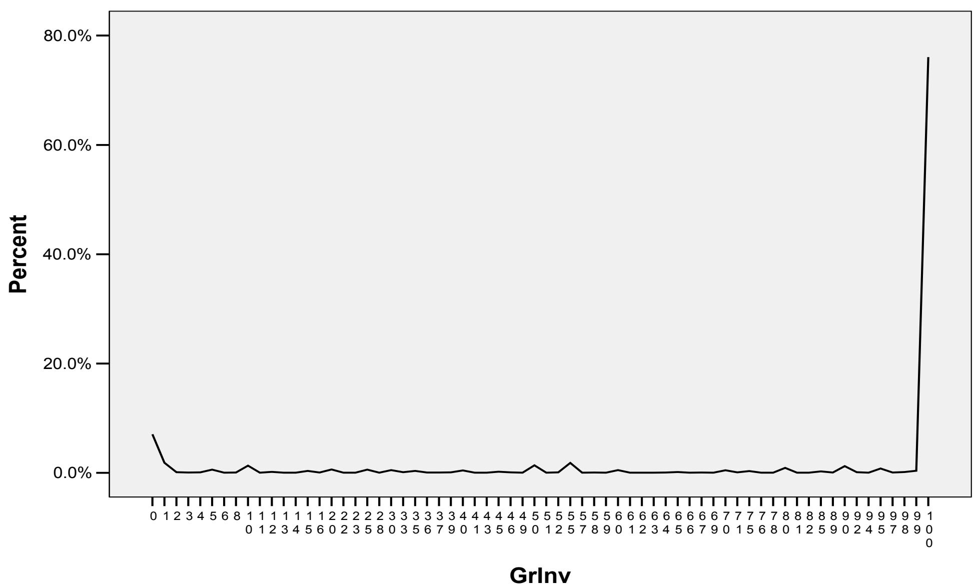
Figure 3

Relative frequency at which each strategy was chosen, by MPCR

Frequency of strategies MPCR=.3



Frequency of strategies, MPCR=.5



S

Figure 4

Observed proportion of zero and full contributions per round and proportions in the Pareto dominant equilibrium, by MPCR

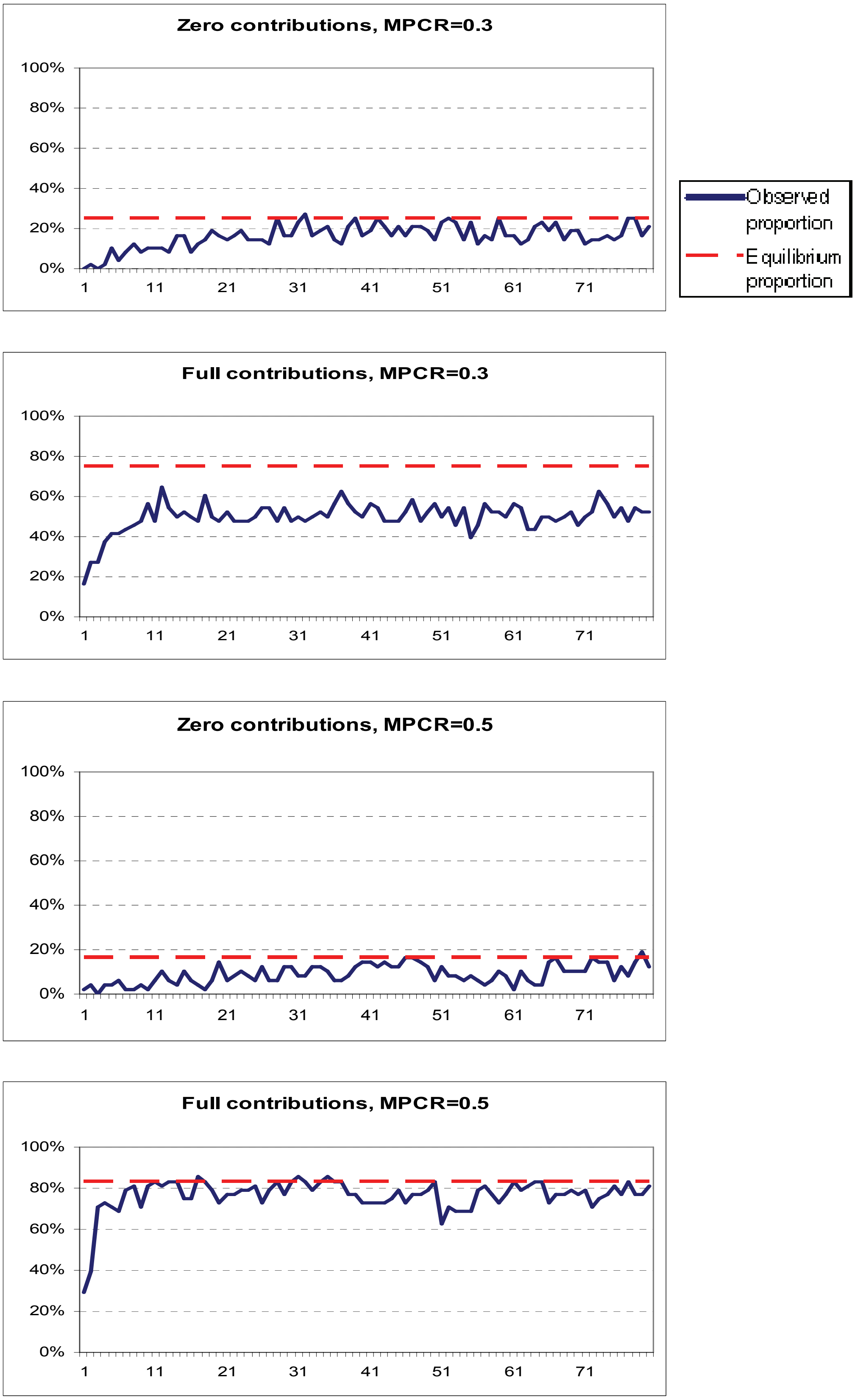


Figure 5 A

Raw frequencies per session MPCR=0.3

Zero Contributions | **Full Contributions**

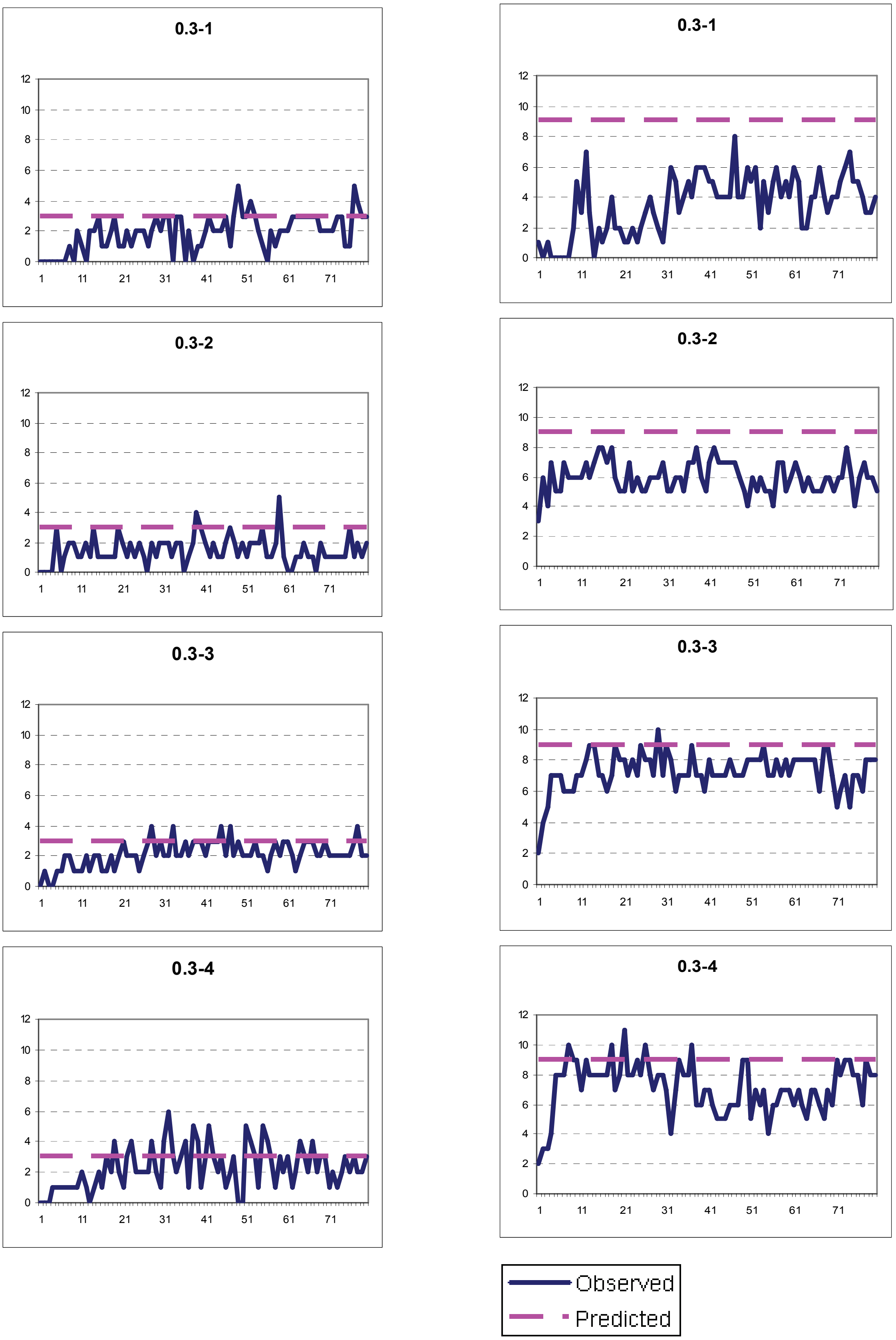


Figure 5 B

Raw frequencies per session. MPCR=0.5