The meritocracy as a mechanism to overcome social dilemmas

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10. February 2007

THE MERITOCRACY AS A MECHANISM TO OVERCOME SOCIAL DILEMMAS

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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, particularly in a discrete implementation, 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.

Comment [a1]: Important comment by Stefan: all get the same in theend.

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]

Comment [A2]: i could put a ref here for the extreme competiton article but may not be suitable for aer

[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 founded the first Mongol empire, and conquered large regions of Asia. He broke with tradition by placing warriors in his military hierarchy based on loyalty and ability only, 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. *N* Participants are randomly assigned to groups of fixed size *n*. Group members then each decide simultaneously and anonymously how much of their individual funds *w* to keep for themselves, and how much to contribute to their group account. Contributions to the group account are multiplied by a factor *g* representing the benefits from cooperation before being equally divided among all *n* group members. In the remainder of this paper, we denote the rate *g/n* by *m*. It is the marginal per capita return (henceforth, MPCR) to each group member from an investment in the group account. As long as ($1<g<n$) [5] the game is a social dilemma since efficiency is maximized if all participants contribute fully, but each individual's dominant strategy is to keep her endowment while receiving her share

Comment [A3]: In fact, isaac, walker & thomas 1984 this experiment was conducted after that conducted by Isaac, McCue and Plott (1985), but due to publication lags preceded it in print.

Comment [A4]: check whether walker 1981, what this is - no his his the paird diff mech not the vcm

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

of the group account. The VCM's widely replicated result is that the equilibrium of 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 assigned to groups at random. 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 based on individuals' contributions to the group account. At each round, all 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 (see below) 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 its formal treatment) must therefore cover multiple groups, which increases the model's realism. Under naturally occurring circumstances too, cooperative groups do not exist in isolation but are part of a larger social fabric.[6]

The MM has a close to Pareto-optimal equilibrium: 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 remains one of them, underscoring that the game retains some social dilemma properties, but with the introduction of competitive group assignment these can be overcome since there is now an additional, asymmetric pure strategy equilibrium that is close to Pareto optimal. In this equilibrium most (i.e., more than N-n) participants contribute their entire endowment, and only the remainder contribute nothing[7]. To illustrate, Tables 1A and 1B shows the equilibria for the version of the MM game experimentally tested in Sections IV and V of this paper, where N=12, n=4, the individual endowment w is 100 tokens, and the MPCR m is either 0.3 or 0.5. The close-to-Pareto-optimal equilibrium configuration is shown in Row 16 (for MPCR=0.3) and 20 (for MPCR=0.5). The Table lists, in addition to this quite efficient equilibrium and the aforementioned equilibrium of non-contribution by all (Rows 1 and 17, respectively), further equilibria with very low group contributions. Such additional, low-efficiency equilibria emerge in the stylized environment of an experiment, where the strategy space needs to be discretized for purposes of experimental implementation. Their exact number and structure are MPCR dependent. They are of limited practical importance since **A)** they arise only due to unavoidable stylizing of the game for an experimental setting, and most importantly, **B)** the payoff-dominant equilibrium, which holds in both continuous and discrete cases (Harsanyi & Selten, 1988) is without doubt the coordinating principle of the

Comment [a5]: THIS MUST FIT WITH THE PROOF. RECALL THE BOUNDARY CONIDTIONS IN THE THEOREM. COMPARE THIS TO WHAT I JUST SAID ABOUT THE MPCR IN THE STANDARD VCM. I THINK THE BOUDNARY CONDS FOR THE MM ARE MORE STRINGENT. The only boundary condition is m.

Comment [a6]: Inserted after submis. In fact I hcnaged this whole paragraph

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

[7] As long as the boundary conditions of the Theorem in Section II.A are satisfied.

game in empirical tests (see Section V). [8]We now proceed to a formal treatment of the continuous version of the MM, which is easier to analyze and possibly more realistic since real-word MM contributions are rarely monetary,[9] before once again turning to the equilibrium configurations of the MM's experimental test later in the paper, where the strategy space is by necessity discrete.

Comment [a7]: Changed after submission

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II.A. Formal equilibrium analysis

Define the meritocracy mechanism (MM) as a game with N players. As in the VCM, each player $i = 1, \ldots, N$ has an endowment $w > 0$, makes a contribution $s_i \in [0; w]$ to a group account, and keeps the remainder $(w - s_i)$ in her private account. After their investment decisions, all players are ranked according to their group account contributions with ties broken at random, and divided in G groups of equal size n ($G = N/n$). The n subjects with the highest contributions are put into group 1; the following n subjects with the next highest contributions are put into group 2, and so on. Without loss of generality, let $s_1 \geq s_2 \geq \ldots \geq s_N$, i. e. group 1 consists of players 1 to n, group 2 of players $(n+1)$ to $2n$ and so on. After subjects have been grouped, their payoffs are computed. Each player's payoff π_i consists of the amount kept in her private account, plus the total group contribution of all the players in her group multiplied by the MPCR $m \in (1/n; 1)$:

$$\pi_i = w_i - s_i + m \sum_{j=i-(i \bmod n)+1}^{i-(i \bmod n)+n} s_j$$

Observation 1: Obviously, the strategy profile $s_1 = s_2 = \ldots = s_N = 0$ is an equilibrium: since $m < 1$, no player can profit from contributing a strictly positive amount to the group account if all others give zero.

Comment [a9]: Cut by anna 7 april Payoffs from the two accounts are as follows: Investments in the private account, without loss of generality, are multiplied by 1. Contributions to the group account are multiplied by a factor g ($1<g<n$) before being equally divided among all n group members. Denote the rate g/n by m. m is the marginal per capita return (henceforth, MPCR) to an individual group member from an investment in the group account.

Comment [a10]: Stefans response to anna: Yes, we do need this claim, as the pure rules of the game do not require that players are ranked prior to their decisions regarding their contributions. However, assuming s1 >= s2 >= s3 ... >= sN makes no formal difference and simplifies notation

Comment [a11]: Stefans response to anna: m > 1/n constitutes the social dilemma characteristic. It is just the rule of the game. At this point, the text only describes the game. The later Theorem will then ask for stronger requirements. So it should be like this.

Comment [a12]: Deleted by anna In what follows we derive the MM's pure strategy equilibria for the continuous case.

Comment [a13]: In the eappx roumen goes thru this proof and looks at all cases. E.g. in case 1 we say that contrary to cont case it is poss that the # of people contributing the highest poss amount IS divisible by n, because of discreteness. In case 2 I say unlike cont case … have lemmas in the proof. Then in discrete he can say lemma 1 does not really work for discrete case, then lemma 2 does not work, etc.

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[8] Interestingly, in all equilibria involving contributions including the payoff dominant one, the expected payoffs from the different strategies are quite similar even though the ex-post payoffs, and the average payoffs per group, vary significantly.

[9] And even in the monetary case, micropayments are becoming increasingly common.

Consider now the case in which some players make strictly positive contributions. Let $l = \max_i \{s_i \mid i = 1, \ldots N\}$ denote the highest contribution, L the set of players contributing l (i.e. $s_i = l \; \forall \; i \in L$), and $b = |L|$ the number of players contributing l. Clearly, $b < N$, else each player would profit from unilaterally changing her contribution from l to zero.

Observation 2: When some strategies are positive (b mod n) > 0, i.e. in equilibrium a high contributor $i \in L$ is grouped with positive probability with some other player(s) contributing less than she does. If b mod n were zero, player i, who at present contributes l, could reduce her contribution by a small ε and still remain grouped exclusively with high contributors. For the same reason b must be larger than n.

Lemma 1: When some strategies are positive, the highest contribution l cannot be smaller than w.

Proof: Since a high-contributor $i \in L$ is grouped, with positive probability, with at least one player who contributes less than l, her expected payoff $E\pi_i$ is smaller than $w - l + m\,n\,l$. Assume l were smaller than w and let $\Delta = w - l + m\,n\,l - E\pi_i$ ($\Delta > 0$). Let player i increase her contribution from l to $l' := \min\{l + \Delta / (2\,(1-m));\, w\}$. Then, player i will be grouped with only high contributors with certainty and her payoff is [10]

$$
\begin{aligned}
& w - l' + m(n-1)l + ml' \\
& \geq w - l - \frac{\Delta}{2-2m} + mnl - ml + ml + m\frac{\Delta}{2-2m} \\
& = w - l + mnl - \Delta/2 \\
& > w - l + mnl - \Delta\,.
\end{aligned}
$$

Thus, contributing l' makes player i better off. Consequently, in equilibrium the highest positive contributions cannot be smaller than w.

[10] The weak inequality "≥" in the second line holds strictly (">") if $l' = w$. If $l' = l + \Delta / (2\,(1-m))$ it holds with equality ("=").

Lemma 2: When some strategies are positive and the highest contribution to the group account is *w,* there cannot be another player *j* with a contribution $0 < s_j < w$.

Proof: Let $b > n$ players contribute w and define $z := (b \text{ mod } n)$. Consider player *j* who contributes the maximum among all players $i \notin L$. Assume first that there were no ties with respect to the group membership of player *j*. Then player *j* could contribute slightly less and remain in that same group with certainty. This cannot be an equilibrium. If, on the other hand, we allow for player *j* being tied for group membership, then with probability *p* she will be in a group in which the highest contribution is s_j. Only with probability (1-*p*), she will be in a group in which (*n*-*z*) payers contribute s_j and *z* players contribute *w*. Player *j*'s expected payoff is therefore:

$$E\pi_j \leq w - s_j + p\,mns_j + (1-p)\,m\big((n-z)s_j + zw\big)$$
$$= w - s_j + m(n-z)s_j + mzw - pmz\big(w - s_j\big).$$

If player *j* increased her contribution to *l'* = min{s_j+1/2 *pmz* (*w*-s_j)/(1-*m*); *w*}, she would be in a group with a higher total contribution with certainty. Her alternative payoff π_j' can be estimated with respect to a lower bound by[11]

$$\pi_j' \geq w - s_j - \frac{1}{2}pmz\frac{w-s_j}{1-m} + m\left((n-z)s_j + \frac{1}{2}pmz\frac{w-s_j}{1-m} + zw\right)$$
$$= w - s_j - \frac{1}{2}pmz\frac{w-s_j}{1-m}(1-m) + m\big((n-z)s_j + zw\big)$$
$$= w - s_j - \frac{1}{2}pmz\,(w-s_j) + m\big((n-z)s_j + zw\big).$$

The difference $\pi_j' - E\pi_j$ is:

$$\pi_j' - E\pi_j \geq \frac{1}{2}pmz\,(w-s_j) > 0\,.$$

Thus, player *j* would profit from unilaterally deviating by increasing her contribution.

Lemma 3: In any equilibrium with positive contributions, the number $N - b$ of players contributing zero is smaller than *n*.

[11] Again, the weak inequality "≥" holds strictly (">") if *l'* = *w*.

Proof: It was shown above that in equilibrium (b mod n) > 0. Consequently (($N-b$) mod n) > 0 as well. If ($N-b$) were larger than n, then any zero contributor could increase her payoff by contributing some small ε and become with certainty a member of the mixed group, in which some members contribute their entire endowment w. In this case her expected payoff is clearly higher than if she were grouped with these same players only with some probability $p < 1$.

The following observation summarizes the above findings.

Observation 3: In equilibrium each player contributes either zero or the entire endowment w. Moreover, the number b of players who contribute the entire endowment is either zero or larger than N-n.

Based on Observation 3, the following Theorem specifies all equilibria of the MM.

Theorem: If $m < \frac{N-n+1}{Nn-n^2+1}$ the only equilibrium of the MM is that all players contribute nothing. If m is of the form $m = \frac{N-n+z}{(N-n)(n-z+1)+z}$ for $z \in \{2, 3, \ldots, n\text{-}1\}$, then there exist additionally, almost efficient equilibria in which $b = N\text{-}n\text{+}z\text{-}1$ or $b = N\text{-}n\text{+}z$ players contribute w and the remaining $n\text{-}z\text{+}1$ or, respectively, $n\text{-}z$ players contribute zero. If $\frac{N-n+1}{Nn-n^2+1} < m < 1$[12], but m is not of the above form, then there exists exactly one $b \in \{N\text{-}n\text{+}1, N\text{-}n\text{+}2, \ldots, N\text{-}1\}$ such that b players contributing w and the remaining N-b players

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[12] As N becomes large this condition converges to the Pareto optimality condition or $\frac{N-n+1}{Nn-n^2+1} \to \frac{1}{n}$ as $N \to \infty$.

contributing zero is an equilibrium. Besides these almost efficient equilibria and an equilibrium of non-contribution by all, there are no further equilibria.

Proof: According to Lemma 3, in all equilibria with positive contributions, the number b of players who contribute their endowment w is larger than N-n. As above, $z = (b \bmod n)$. Thus, for all equilibrium candidates with positive contributions $z \in \{1, 2, \ldots, n\text{-}1\}$.

Consider a full contributor. Her expected payoff is

$$mw\left(\frac{z}{N-n+z}z+\frac{N-n}{N-n+z}n\right)=mw\left(\frac{z^2+Nn-n^2}{N-n+z}\right).$$

It never pays for this player to lower her contribution by ε since she would then be grouped with certainty with at least some zero-contributors. If the same player changes her contribution to zero, her payoff is $w+mw(z-1)$. Thus, in equilibrium

$$\begin{aligned}&mw\left(\frac{z^2+Nn-n^2}{N-n+z}\right)\geq w+mw(z-1)\\ \Leftrightarrow\ &m\left(\frac{z^2+Nn-n^2}{N-n+z}\right)\geq 1+m(z-1)\end{aligned} \tag{1}$$

must hold, which is independent of the initial endowment w. With respect to z, the left hand side of (1) grows more slowly than the right hand side.[13] This means that if the inequality is violated for $z = 1$, in which case a full contributor has an incentive to change her contribution to zero (i.e. there is no equilibrium with $z = 1$), then there is also no equilibrium in which $z > 1$. Thus, we will start examining the equilibrium candidates where $z = 1$, and will then proceed to the candidates where $z = 2, \ldots (n\text{-}1)$.

For $z = 1$, one obtains from (1) the following necessary equilibrium condition, which provides a lower bound for an MPCR that allows for equilibria with full contributors:

[13] The right hand side grows with a rate of m. The left hand side can be rewritten as $m\dfrac{z^2+n(N-n)}{N-n+z}$ which grows more slowly than $m\dfrac{z^2+z(N-n)}{N-n+z}=mz$, which again grows at a rate of m.

$$m\left(\frac{Nn-n^2+1}{N-n+1}\right)\geq 1 \Leftrightarrow m\geq \frac{N-n+1}{Nn-n^2+1}. \tag{2}$$

Now, consider the situation of a zero contributor. Her payoff is given by

$$w+mwz$$

If the zero-contributor deviates to contributing w, her expected payoff changes to

$$mw\left(\frac{z+1}{N-n+z+1}(z+1)+\frac{N-n}{N-n+z+1}n\right)$$
$$=mw\frac{(z+1)^2+Nn-n^2}{N-n+z+1}.$$

This gives the second necessary equilibrium condition:

$$\begin{aligned} &w+mwz \;\geq\; mw\frac{(z+1)^2+Nn-n^2}{N-n+z+1} \\ &\Leftrightarrow\; 1+mz \;\geq\; m\frac{(z+1)^2+Nn-n^2}{N-n+z+1} \end{aligned} \tag{3}$$

which implicitly sets an upper bound for m. For the special case of $z = 1$, this upper bound is

$$\begin{aligned} &1+m\geq m\frac{2^2+Nn-n^2}{N-n+2} \\ &\Leftrightarrow m\leq \frac{N-n+2}{Nn-n^2-N+n-2} \end{aligned} \tag{4}$$

which is the lower bound of m for an equilibrium with $z = 2$.

Three observations are crucial: First, the upper bound (4) is larger than the lower bound (2) for the MPCR m and consequently there is a nondegenerate interval of MPCRs for which equilibria exist in which $z = 1$. Moreover, for MPCR values within this interval the only two pure strategy equilibria are $s_1 = s_2 = \ldots = s_N = 0$ and $s_1 = s_2 = \ldots = s_b = w$, $s_{b+1} = \ldots = s_N = 0$ ($b = N - n + z$). Second, if m increases above the upper bound (4), there is no longer an equilibrium with $z = 1$. However, a violation of inequality (4) (or (3), respectively) exactly yields the necessary condition for an equilibrium with $z = 2$ (or $z' = z+1$ in the general case)

Comment [a14]: (excluding the end points) end points included is called on this interval from the perspective of a full contributor. Thus, if (2) is fulfilled, but one/some of the upper bounds of the MPCR for a given z is violated, then there exists an equilibrium with a larger z. Third, if the upper bound (3) yields with equality, then there exist equilibria with both z and $z+1$. This concludes the proof.

Discrete strategy space: If the strategy space is discrete rather than continuous the above equilibrium analysis holds, but additional pure strategy equilibria can emerge. The reason for this is quite intuitive. Changing one's contribution by a very small amount is close to costless; changing it by, say, one unit token as in an experiment (see Sections IV and V) is not. Hence, if the strategy space is discrete rather than continuous, additional stable configurations may exist where it does not behoove a participant to unilaterally change his contribution by an entire unit token even though it would pay off to change it by a small ε. In our experimental test of the MM (Section IV), such additional stable configurations logically emerge when group account contributions by other participants are low or the MPCR is low. Table 1, which lists all pure strategy equilibria possible under the two MPCR conditions tested experimentally (with an integer strategy space of $s_i \in \{0, 1, 2, \ldots, 100\}$ tokens) illustrates this point. The equilibria that hold in both the continuous and the discrete case are highlighted in the table. The additional equilibria listed (Rows 2-15, and 18, 19) are of little practical importance since they are clearly payoff inferior and most importantly, do not account for actual behavior. [14] The payoff dominant equilibrium (Harsanyi & Selten, 1988) described in the Theorem above is clearly the behavioral organizing principle (see Section V), a fact that makes the MM a simple and effective mechanism to foster cooperation. Another reason for the MM's practical significance as illustrated in its existing applications in the field is the fact that the group good in the MM covers a relatively broad spectrum of goods.

Comment [a15]: For $z = n$, $m = \dfrac{N-n+z}{(N-n)(n-z+1)+z} = 1$; and for any m > 1) fully contributing is the dominant strategy.

Comment [a16]: 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 in the table.**this is no longer quite correct since there are now in some cases 2 pos stras.**

Comment [a17]: This is in spite of the fact that the social dilemma structure of the game is at least partially maintained when one moves from the VCM to an MM, as illustrated by the fact that non-contribution by all **(always? See roumens results when they come in)** remains one of the equilibria, just as it was in the standard VCM.

[14] See http://anna.rvik.com/M/dis.pdf for the formal analysis of all equilibria in the discrete case.

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 contribution-based rather than arbitrary excludability **A)** inefficient equilibria still exist, **B)** there is still no100% efficient equilibrium, 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 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),

Comment [A18]: and to extract the properties of static mechanisms that induce convergence. **This** motivates the research reported in this paper. **We select two Nash e#cient mechanisms to implement in a laboratory: the Basic Quadratic mechanism by Groves and Ledyard #1977# and the Paired Di#erence mechanism by**Walker #1981#**.** While the Basic Quadratic mechanism has been studied in laboratories, the PairedDi #erence mechanism has not been systematically studied in laboratories. **A** comparison of these two families of mechanisms has not been performed either.

Comment [A19]: called compensation mechs. work for a variety of settings incl. pg.

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.[15] 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. Debate about the extent to which the group account is congestible, excludable, or rival is therefore unnecessary.[16] Further, the linear and commonly known monetary payoff functions of the VCM and MM 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.

Comment [a20]: Both mechanisms are rooted in the experimental tradition where the group output, like all other incentives that are experimentally modeled, is ultimately a pool of money-divisible and rival.

Since it covers a broad range of team production goods, the MM model is applicable as a social or organizational structure that increases efficiency or effectiveness

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

[16] 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.

in a variety of contexts. We next show that its equilibria involving positive contributions may be affected by risk attitudes, but are quite robust to errors by single players.

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* while non-contribution guarantees a payoff of at least *w*. 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*. All these facts taken together mean that contributing, never an equilibrium strategy in the VCM, is even less attractive there the lower the MPCR. All these facts hold for the MM as well, but with additional twists.

Compared to the VCM, the MM involves additional strategic uncertainty. First, there is now always a choice between equilibria. Second, in any equilibrium involving group contributions, a contributor's final payoff depends on the random process that solves the ties for group membership. Finally, as shown in Table 1, the payoff from contributing is usually slightly lower than the payoff from free-riding, be the latter expected, or even

Comment [a21]: The decay is slowest if *m* is close to 1[6], fastest if *m* approaches *1/n*

Comment [a22]: , since the range of possible earnings and losses associated with contributing is shifted downwards if the MPCR is lowered

Comment [a23]: This is in spite of the relatively large probability that a contributor will be grouped with other contributors which reduces the probability of being free-ridden compared to random grouping.

Comment [a24]: the MPCR determines their number and structure guaranteed (The latter is the case if less than N-n participants free-ride).[17] The higher the positive contributions in a strategy profile are, the greater is this difference. In an experimental test of the MM, if subjects are sensitive to how efficient payoffs differ by MPCR, or are averse to loss relative to their original endowment level w (Kahneman & Tversky, 1979), or are responsive to how free-rider payoffs compare to cooperator payoffs in equilibrium, they might be more reluctant to contribute fully under MPCR=0.3.

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. If a contributor reduces his contribution he is placed in a lower group with increased probability if not with certainty. This reduces his payoff, but the incentives of other contributors are well protected from such an individual downward deviation. The remaining contributors' likelihood of getting into a high group, and hence their payoff, would actually increase! They have therefore no reason to drastically drop their contributions in such a case. In this regard the MM differs significantly from weakest-link games or step-level public goods mechanisms, (discussed in the next section), where a deviation downward by a single player can be quite disastrous to overall efficiency, since it leads to others' investments being wasted, which in turn drives everyone's incentives toward a much less efficient equilibrium with lower (or even zero) team contributions.

III. RELATED GAMES AND EXPERIMENTAL FINDINGS

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.,

[17] The sole exception is the middle strategy in the three-strategy asymmetric equilibrium in Row 10 of Table 1A, where the expected payoff from contributing 2 tokens exceeds by 0.02 tokens the certain payoff from contributing nothing.

Comment [a25]: cut out by anna for resubmission. Further, in all equilibria under MPCR= 0.5 the highest payoff a contributor can possibly earn if she is assigned to a homogeneous group equals what a non-contributor receives with certainty. However, under MPCR=0.3, in cases in which free-rider payoffs are certain, an equilibrium with positive contributions may be even less favorable to a contributor: Even her highest possible payoff is often slightly lower than what a free-rider receives with certainty.**this is no longer true with the new 3-strategy equiblria.**

Comment [a26]: cut by anna april 9
Since the game extends across strata, but final payoffs are computed within strata. Therefore, one or even several players' deviation have relatively little impact on a contributor's expected earnings and often have a positive, rather than a negative, effect.
Since payoffs are calculated on the group level, and their likelihood of getting into a high group increases.

Comment [a27]: general **risk dominance only between 2 games.**

Comment [A28]: it does not lead to unique predictions about individual behavior because the equlbrium is asymmetric.

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 among its equilibria, 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.[18] In an experiment by Cinyabuguma, Page and Putterman's (2005) there was greater mobility; subjects were informed about each others' historical contributions[19] 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

[18] 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.

[19] 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.

Comment [a29]: See, e.g., Binmore's (1989) critique that equilibrium selection will remain a contentious area, and that the Harsayni-Selten (1988) refinement is just one of many theories of equilibrium selection.

Comment [A30]: In contrast to the mechanism design literature, in experimental VCM studies there is usually no attempt to modify the equilibrium structure of the game except in minor ways Rather, psychological or social mechanisms are hypothesized to affect off-equilibrium cooperation rates. Exceptions are for example: changing the form of the payoff function, e.g. from linear to quadratic, which moves the equilibrium to the interior of the strategy space, changing the MPCR.
quarterly journal of economics, group size effects)

Comment [a31]: lowest person in group 1 goes down, highest goes up, this is common k, see their instructions

Comment [a32]: introduce exclusion from the group output, rather than the group itself, again limited to the least contributor. If all contribute equally, there is nobody to exclude, hence all symmetric contribution configurations are equilibria. This form of exclusion differs from the MM since there is no contribution-based restratifcation (in fact, the authors use a partners treatment), but it is noteworthy that competition within a team for access to the group output, rather than ... [1]

Comment [a33]: , which stays together in same grp over all rounds. in the croson et all study

Comment [A34]: *The Cinambuya study differs from ours in that*, group membership and group size is endogenous and, unlike in the meritocracy game, group size is n ... [2]

Comment [A35]: yes this is right the same authors published on related issues in 05 and 06

Comment [A36]: if given the opportunity to excludeFRs the latter, cooperators do strive to exclude free-riders which in turn raises contributions

Comment [A37]: Public good; interact with person. Same for private goods. Trust. Our result is more compelling since it shows no need for that. Only thing u know is that pe ... [3]

Comment [A38]: exaples of endogenous rankings.problem with putterman is a 2-sided ranking. Prefs on both sides there is no equm. Markets whre there is prefs for each other ... [4]

Comment [a39]: over three subsequent rounds

Comment [A40]: Up to 70% *(compared to equilibrium or control condition?)*

decentralized and endogenous as in Page et al.'s study. We note however that centralized ranking, as in the MM, is also common.[20]

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 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,

Comment [A41]: the equilibria are Pareto deficient. and which may be weak ; sometimes there is 2 equa in both the market is either filled to capacity c(with c entrants) or is filled just below capacity (c-1 entrants).

Comment [A42]: There is usually, structurally, 2 pure strategy equilibria in the way that amnon set it up. they are very similar in efficiency. Mixed strategy equilibria also exist. Symmetric. clearly, but i think that asymmetric mixed stra equa exist as well. I do think that there is a way to have only one. but not sure..

Comment [A43]: If we keep the payoff from "staying out" constant, the number of asymmetric pure strategy equilibria then depends, strictly speaking, not only on c but also on the number of participants. .However, from a purely structural perspective, there are two weak pure strategy equilibria, in which payoffs between the two choices (enter/stay out) are equ. bevore i said this is in teh pure stra eqm but note that if they played mixed stras you would also observe proportions even though they are not in the players' minds.

Comment [A44]: see my test of equilibria for this game. if v, the payoff from staying out is even, i can only see one equilibrium in pure strategies, and ;; really tehre are 2 equilbria types, payoffs very close in both. then the exact # of eqma depends on the number of players.

Comment [a45]: , as if by "magic" (Kahneman, 1988, p.12).

Comment [A46]: this is from seale and rapoport

Comment [A47]: seale and rapoport say no mistra, and also rapoport 1995

[20] 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.

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).[21]

There is much more strategic uncertainty associated with high contributions in WL game than in the MM. In the WL game, a deviation downward by even a single "weak link" adjusts everyone's payoff downward, and expenses associated "higher" choices are wasted. As mentioned above, the payoff for a "high" choice in the MM is quite robust to deviations downward by single players. A similar comparison holds when the MM is compared with the step-level VCM mechanism.

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

[21] 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.

Comment [A48]: p. 151

Comment [A49]: Even if the market "capacity" *c*, varies from trial to trial the equilibrium is reliably achieved (see, e.g., Rapoport, 1995; Sundali et al, 1995)

In sum, if there are multiple equilibria coordination on the Pareto optimal equilibrium may be problematic for group members who decide simultaneously even though competition of some sort may increase efficiency. On the other hand, coordinating on the specific proportions of an asymmetric equilibrium seems surprisingly easy for experimental subjects. The MM"s most efficient equilibrium (see Table 1) requires both types of coordination. An additional factor to complicate coordination in the MM is its rich strategy set -101 discrete strategies [0,100] in the case studied here.

Comment [a50]: a choice between entering a market and staying out, appear inconsistent with either mixed or pure Nash equilibria. Here we show that, in this class of game, learning theory predicts sorting, that is, in the long run, agents play a pure strategy equilibrium with some agents permanently in the market, and some permanently out. We conduct experiments with a larger number of repetitions than in previous work in order to test this prediction. We find that when subjects are given minimal information, only after close to 100 periods do subjects begin to appro ... [5]

Comment [A51]: the effect depends, for example, in group size (or the introduction of bonuses. (see, e.g. Brandts & Cooper, 2006) WEber, CAmerer & Knez, 2004; Knez & Camerer 1994)

Comment [A52]: min effort. groups.' The strategic uncertainty that underlies this incentive problem can profoundly affect behavior. Despite payoff-dominance, in VHBB's largegro ... [6]

Comment [A53]: medium effort

Comment [A54]: not quite the same - not all stras are part of an eqm.. not weakest link.. but shows that pareto dominant eqm not always arrived at.

Comment [A55]: At times a learning process eventually leads to an improvement in efficiency over decision rounds

Comment [A56]: intro of bonuses increases coo. group size is 4 and groups stay together over 30 rounds.

Comment [a57]: Isaack smitz and wlkaer conclude: : havior we observed was a very small incidence of groups obtaining the more efficient equilibria and a large incidence of decay to the very low levels of ... [7]

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. [22] In fact, in the majority of instances, the SL-VCM is not very effective at maintaining high contributions.[23] The MM in contrast, as the experimental test described below shows, is quite effective at maintaining efficiency over repeated rounds.

Comment [a58]: raising contributions and in particular at keeping them high over rounds

Comment [a59]: *Hence, payoff dominance does not seem to be the organizing principle.* Dawe says money back guarantee says it made no diff).,

IV. EXPERIMENTAL METHOD

Comment [A60]: We normally expect authors of experimental articles to supply the following supplementary materials (any exceptions to this policy should be requested at the time of submission): 1. The original instructions. These should be summarized as part of the discussion of experimental design in the submitted manuscript, and also provided in full as an appendix at the time of submission. The instructions should be presented in a way that, together with the design summary, conveys the protocol clearly enough that the design could be replicated by a reasonably skilled experimentalist. For example, if different instructions were used for different sessions, the correspondence should be indicated. 2. Information about subject eligibility or selection, such as exclusions based on past participation in experiments, college major, etc. This should be summarized as part of the discussion of experimental design in the submitted manuscript.

Design and participants

The MM was examined under MPCR=0.5 and MPCR = 0.3. 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.

Comment [a61]: Different MPCRs were examined because theoretical predictions for the MM vary with the MPCR (see Table 1). An examination under different MPCRs offers indications about the robustness of the mechanism's performance if conditions vary. Such an examination was even more pressing due to the multiple ways in which the MPCR affects the downside risk of contributing. Second,

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

Comment [A62]: > Hi, Anna,
> The subjects did not have a quiz because the quiz was
> designed only for an MPR of 0.5

[22] 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. 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 occur in equilibrium.

[23] 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).

subject received one hundred tokens to invest (in integer amounts) 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 were ready. [24]

Group assignment. 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.

Comment [a63]: For example, if five subjects contributed the maximum of 100, then each of them had a 4/5 chance of ending up in the highest group, and a 1/5 chance of ending up in the middle group.

End-of-round feedback. 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. .

Comment [A64]: Some subjects may have kept notes.

[24] 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

Comment [A65]: Footnote on ks:note of caution: finite sample. Random but not inde. We could draw in clusters. E.g. Sydney population and Melbourne population are not inde. I assume I did random draw among students. 4 clusters. They influence each other. Max diff between the 2 curves. Ks tests requires random sampling but not necessarily inde of obbs. Experimentsre never have random samples. Data across rounds not inde. We are not aware of importance of this particular assu for the ks test. It cannot deal with cyclic effects such as a distribution over time.

Yates' correction formula to account for low cell counts.

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). [25] 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.

Comment [a66]: Over 80 rounds there is neither any apparent movement toward the Pareto optimal outcome of full contribution by all, nor downward trend toward a less efficient solution.

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

[25] 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. [26] 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. [27] 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).

Comment [A67]: The Figure provides generally support for the prominence hypothesis (Selten, 19xx(that people tend to make choices in multiples of five. However, for MPCR=0.3, contribution decisions are much less spread than in a regular VCM and the frequency peaks at the multiples of five are much smaller. (See e.g., Gunnthorsdottir, 2001 for comparison data in the regular VCM).Such peaks are barely noticeable in the case of MPCR=0.5.

Result 4

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 A and B, rows 16 and 20). 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.[28]

Comment [A68]: A ks test for all data all 80 rounds for 0.5 rejects that data are from hypothesized distribution. D=0.1, crit val -0.022. also rejected for 0.3.
A ks test for each session rejects this at 0.01 for all sessions as well. But the values are close. I
The ks tests per sess reject the o because of how the test is built. Its about the divergence predicted-observed cum fre.
As you keep going andmre intermed conribs come into the cum fre the divergence with the lo precited com fre (based on fre of zero congribs) increases.
Hence the ks test does not capture well.

---

[26] 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.

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

[28] 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 [29] fails to reject the null hypothesis that the shape of distributions of intermediate strategies differ by MPCR. Hence, their comparatively lower MPCR did not lead MPCR=0.3 subjects to systematically attempt any of the equilibria with lower positive contributions (listed in Table 1).[30] Figure 3 confirms that if subjects intended to somehow hedge their bets under MPCR=0.3, their hedging strategies covered the entire strategy space.

[29] 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”.
[30] 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, $p \leq 0.20$).

Comment [a69]: (rough count)

Comment [a70]: under mpcr = 0.3 , the frequency of both zero and full contributions is only 2/3 of what is expected.

Comment [a71]: median

Comment [a72]: i did not really develop that - hence need to rephrase

Comment [a73]: However,as a percentage of total choices made, under MPCR=0.5, 100 contributios (rough count) and zero contributions (rough c) are 7 and 8% less than expected. **For mpcr=0.3, the differences are 9% (for zero contriutions) and 26% respectively. (see figure xx).**

Comment [a74]: Hedging is quite irrational: for example, if in an equilibrium configuration under MPCR-0.3 one player deviates from full contribution and hedges by contributing 50, he is guaranteed a place in the lowest group with N-b free-riders and earns 65 tokens for sure. Had he fully contributed his earnings would have been either 120 or 30 tokens.

Comment [A75]: Our hypothesis is always at the population level. We assume that this comes due to competition. Similar example in siegel and castellan that is a pop of strikes. The question is does it correspond to the model? That it is interactive is part of the design. We know that in round 1 it does no happen, it needs to play in.
It seems to me that ks tests are very robust holt laury on risk use them by accumulating all frequences of the risk qusitonaiiroe (so that each data point is a distribution) and comparing hi and lo stake (with the same subjects, so its essentially paired). Schotter (saved) takes from the first 20 rounds and the last 20 rounds of a 60 round expt. And compares the distributions. Again, they are n ... [8]

Comment [A76]: The treatment effects are as e Conversely, , in 21 out of 80 rounds the null hypothesis that the *distribution of these frequencies 03 has a significantly lower median was rejected in favor of the alternate that the m* ... [9]

Comment [a77]: mean frequences per mpcr are 57.5 vs 184.5. the test however fails to reject the null hypothesis that the frequences for positive contributions that are smaller than half the dneowment differ (p<=0.114, 2-tailed test). T ... [10]

Comment [a78]: are they confused or risk averse? If in mpcr=05 give intermed they msut be confused. Since they can never lose. If in mpcr=0.3 give intermed they may be risk averse.

Comment [A79]: pasted Also, from the standpoint of an individual loss-averse with regard to her current wealth levels (Kahneman & Tversky, 1979), if the MPCR is low, the potential loss to a sole contributor compared to her ... [11]

Result 6

Individual strategies are unsystematic.

Individual choices over trials can be viewed at http://www.agsm.edu.au/~bobm/data. In each of the MPCRs tested, there are actually $\binom{N}{b}$ payoff dominant equilibria, with various players taking one of the two roles, either contributing fully 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. However, 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 Market Entry games where aggregate behavior is also well captured by the equilibrium while individual strategies are hard to account for. [31]

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.

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

Comment [a80]: Re my comparisong papers of how info matters: ochs 1999 in memorial book for amnon (erev & zwick eds) says on p 152: the degree of coord achieved dep on info feedback. If no common knowledge of oversubscribed markets there are more failures (eqm not realized). Less failures if common k of distribution of choices. Means that conditioned their stra elsection on behavior of others, not only their own payoffs.

Comment [a81]: Also at http://anna.rvik.com/M/indls.pdf

Comment [a82]: We study the importance of conditional cooperation in a one-shot public goods game by using a variant of the strategy-method.We find that a third of the subjects can be classified as free riders, whereas 50% are conditional cooperators.

Comment [a83]: Their 2002 aer paper says delicne in contribs is all due to less confusion, not what we want to say yere.

Comment [a84]: European journal, seqntial pg game, type detection

Comment [a85]: 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. says percentage of types that exists.

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. [32]

Comment [a86]: Hence, grouping similar types, even unbeknownst to the participants slows the usual decline in contributions over trials (see, e.g., Gunnthorsdottir, Houser & McCabe, 2007; Ones & Putterman, 2006; Gachter & Thoni, 2005;; Burlando and Guala, 2005; Andreoni, 1995). In the MM in contrast, such a grouping rule is common information, which should provide further assurance to conditional cooperators, and, possibly, even to those who free-ride due to lack of trust rather than in order to maximize payoff (Rapoport & Eshed levy, 1989).

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.) the 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

[32] 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.[33]

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.

<u>Criticisms and extensions</u>

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[34] 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 variable, and players are grouped based on whether their contributions are above or below certain thresholds would be appropriate.

Comment [a87]: The MM's most efficient equilibrium is therefore unlikely to be, for example, a focal point in the sense of Schelling (1960).

Comment [a88]: For example the market entry game it is easy to understand that if enough players have entered there market, given the payoff functions of the two choices, there is a point at which one is indifferent between entering and staying out. in weakest link games, the structure again is obvious. In SL VCM games, too,

Comment [A89]: HOwevr, a meritocracy, as a means of generating welfare (in this case in connection with the generation of collective output), may have an easy fit with human nature as does the market. *(Should we include this paragraph?)*

Comment [a90]: , such as their fairness, and the fact that they place players in positions where they are most suited. their impact on organizational or social effectiveness by positioning players in positions where they are most suited.

---

[33] 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).

[34] 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.

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 have equal endowments, and a noteworthy feature of the MM asymmetric equilibria presented in this paper is that contributors and non-contributors receive approximately the same expected payoffs. 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.

Comment [A91]: moore and Repullo (1988 p. 1198) point out, " . . .the mechanisms weconstruct . . . are far from simple; agents move simultaneously at each stage and their strategy sets are unconvincingly rich. We present such mechanisms to show what is possible, not what is realistic."
Sorting externally is restrictive. However, putterman et al show that endo also works well on B.

Comment [A92]: The aggregate solution is reliably realized. Individual behavior similar to market entry. Looking at the global picture. Don't know why it happens but looking at NEa. Indls means going into psyc sociology. Aer focuses on global perspectives. Indls – erratic like in ME games, should be examined further.

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Comment [a95]: a choice between entering a market and staying out, appear inconsistent with either mixed or pure Nash equilibria. Here we show that, in this class of game, learning theory predicts sorting, that is, in the long run, agents play a pure strategy equilibrium with some agents permanently in the market, and some permanently out. We conduct experiments with a larger number of repetitions than in previous work in order to test this prediction. We find that when subjects are given minimal information, only after close to 100 periods do subjects begin to approach equilibrium. In

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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 1A

Equilibria for N=12, n=4, w_i = 100, and MPCR=0.3. Discrete integer strategy space.

	Strategy configuration (s_{12}, s_{11}, …, s_1) (Expected payoff per strategy in parentheses)	**Efficiency** [35] **%**
1	**0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0** (100.00)	0.0
2	**0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1** (100.10) (100.02)	0.4
3	**0, 0, 0, 0, 0, 0, 0, 2, 2, 2, 2, 2** (100.39) (100.78)	0.8
4	**0, 0, 0, 0, 0, 0, 0, 3, 3, 3, 3, 3** (100.40) (100.06)	1.3
5	**0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1** (100.30) (100.10)	0.7
6	**0, 0, 0, 1, 1, 1, 1, 2, 2, 2, 2, 2** (100.30) (100.20) (100.22)	1.1
7	**0, 0, 0, 1, 1, 1, 2, 2, 2, 2, 2, 2** (100.30) (100.30) (100.28)	1.2
8	**0, 0, 0, 2, 2, 2, 2, 2, 2, 2, 2, 2** (100.60) (100.20)	1.5
9	**0, 0, 0, 2, 2, 2, 2, 4, 4, 4, 4, 4** (100. 60) (100.40) (100.44)	2.3
10	**0, 0, 0, 2, 2, 2, 2, 5, 5, 5, 5, 5** (100.60) (100.62) 100.40)	2.7
11	**0, 0, 0, 3, 3, 3, 3, 3, 3, 3, 3, 3** (100.90) (100.30)	2.3
12	**0, 0, 0, 4, 4, 4, 4, 4, 4, 4, 4, 4** (101.20) (100.40)	3.0
13	**0, 0, 0, 5, 5, 5, 5, 5, 5, 5, 5, 5** (101.50) (100.50)	3.8
14	**0, 0, 0, 6, 6, 6, 6, 6, 6, 6, 6, 6** (101.80) (100.60)	4.5
15	**0, 0, 0, 7, 7, 7, 7, 7, 7, 7, 7, 7** (102.10) (100.70)	5.3
16	**(0, 0, 0, 100, 100, 100, 100, 100, 100, 100, 100, 100)** (130.00) (110.00)	75.0

Comment [a102]: would be better to Do it as a percentage of the maximum return.

Comment [a103]: =5/1200

Comment [a104]: {100.3} {99.3, 100.5} {99.5, 100.4}

[35] Contributions as a percentage of total endowments.

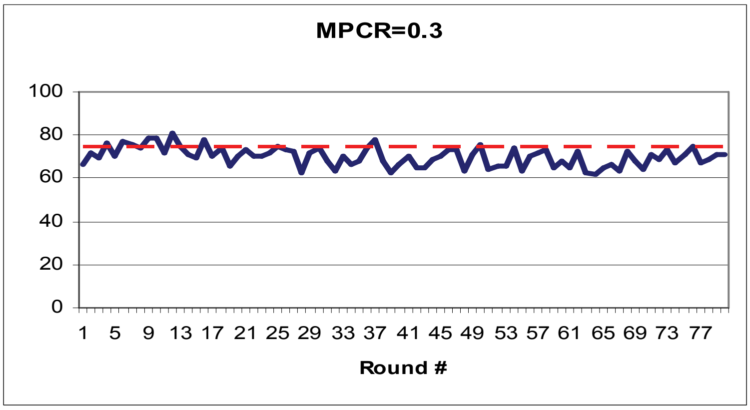
Table 1B

Equilibria for N=12, n=4, w_i = 100, and MPCR=0.5. Discrete integer strategy space.

	Strategy Configuration (s_{12}, s_{11}, …, s_1) (Expected payoff per strategy in parentheses)	**Efficiency**[35] **%**
17	**(0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)** (100.00)	0.0
18	**0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1** (101.00) (100.80)	0.7
19	**0, 0, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2** (102.00) (101.60)	1.5
20	**0, 0, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100** (200.00) (180.00)	83.3

Figure 1

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



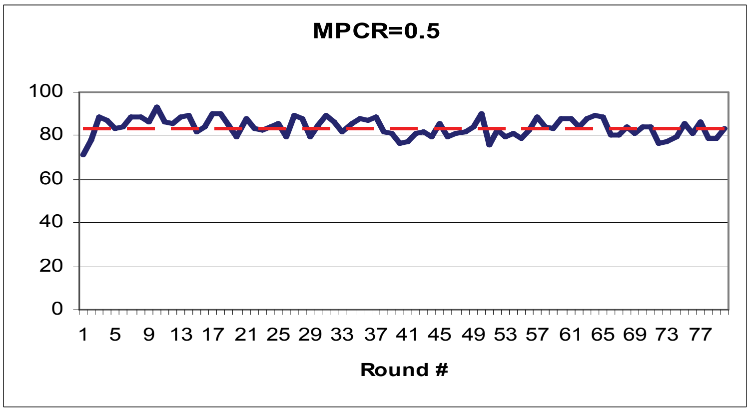


Figure 2A

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

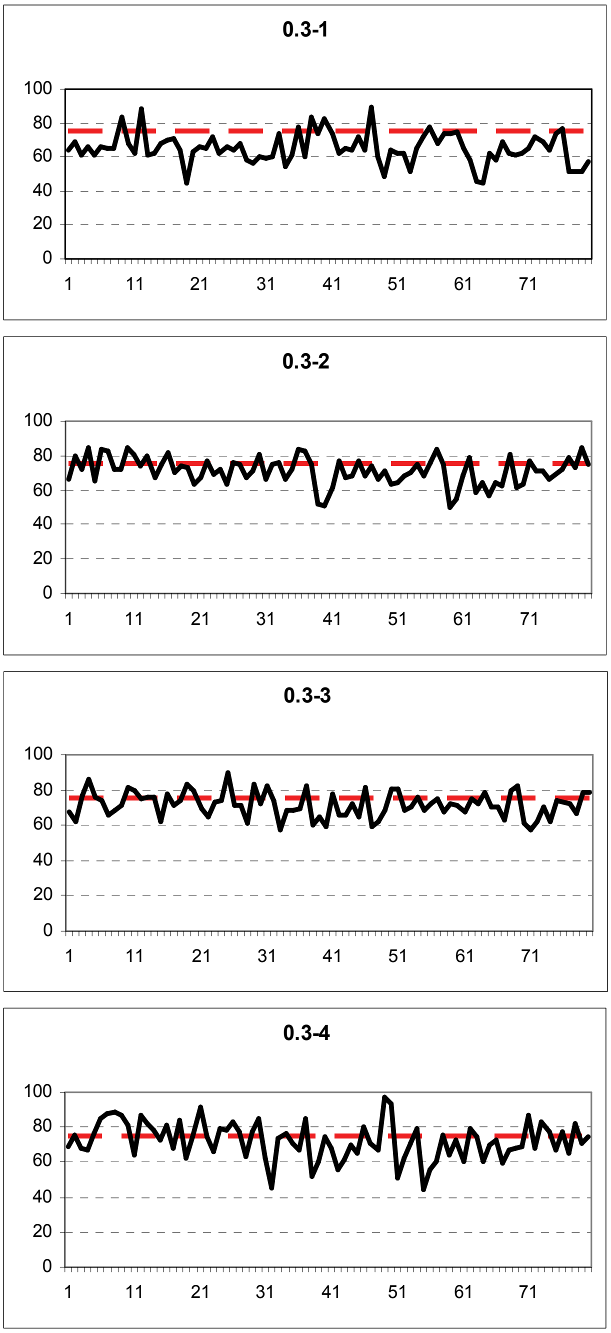


Figure 2B

<u>Equilibrium and mean contributions per round, per session, MPCR=0.5</u>

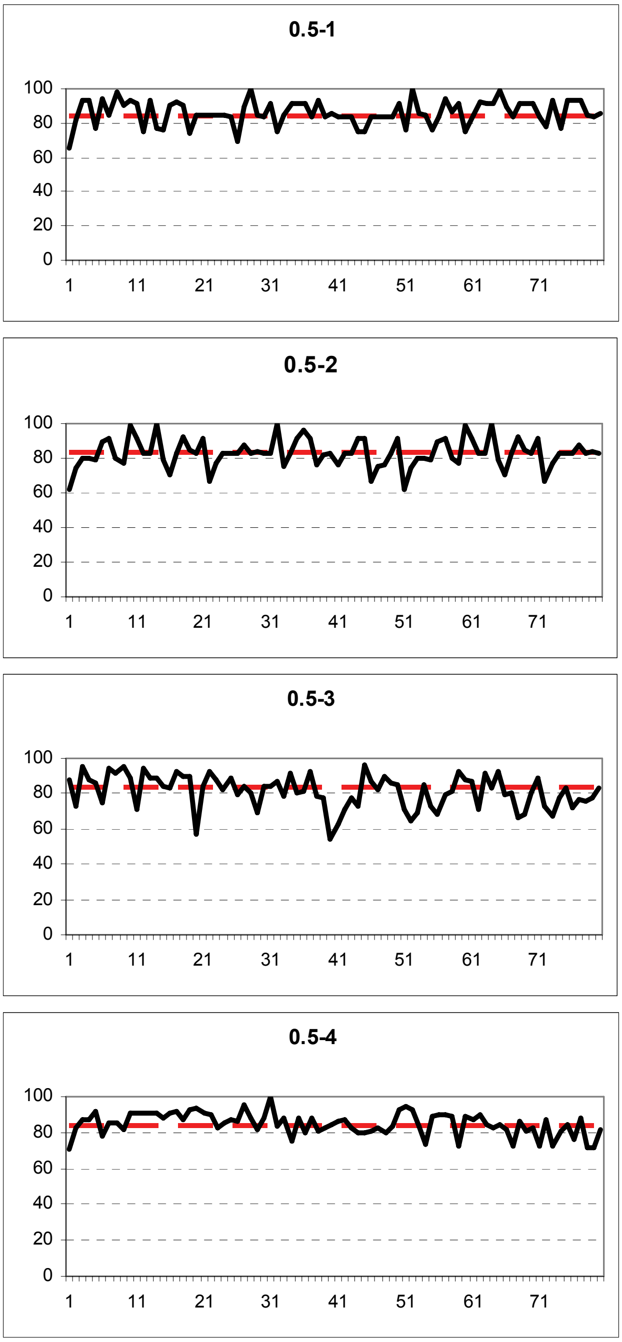
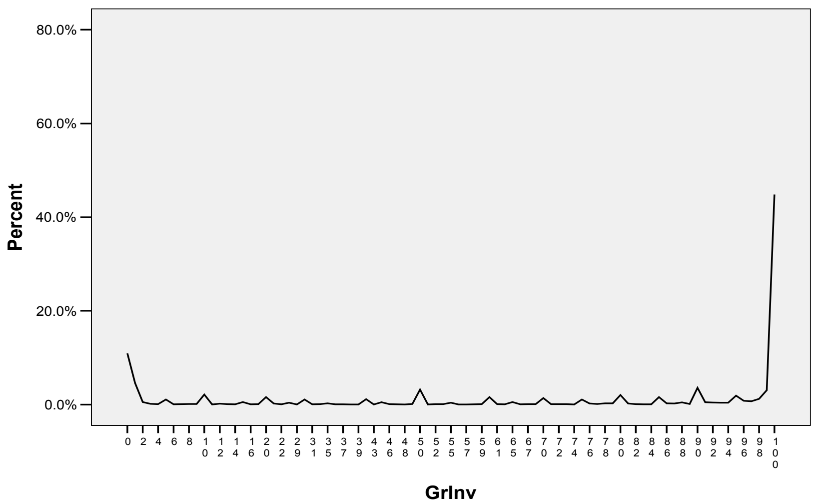


Figure 3

Relative frequency at which each strategy was chosen, by MPCR

Frequency of strategies MPCR=.3



Frequency of strategies, MPCR=.5

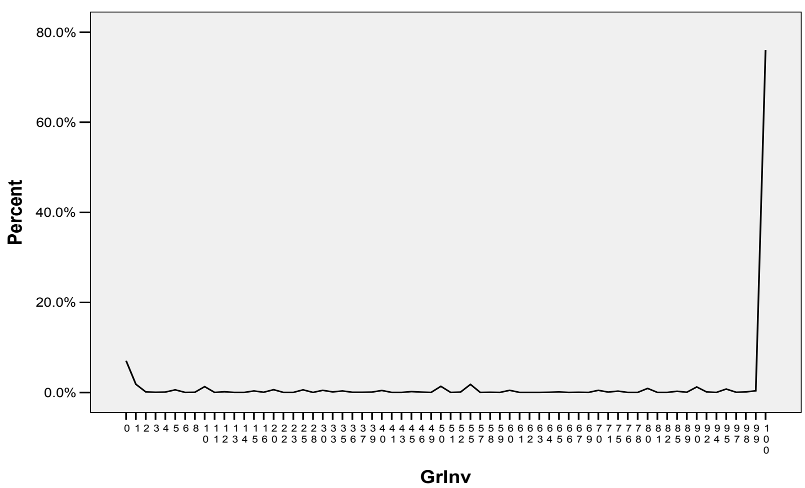


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Figure 4
Observed proportion of zero and full contributions per round and proportions in the Pareto dominant equilibrium, by MPCR

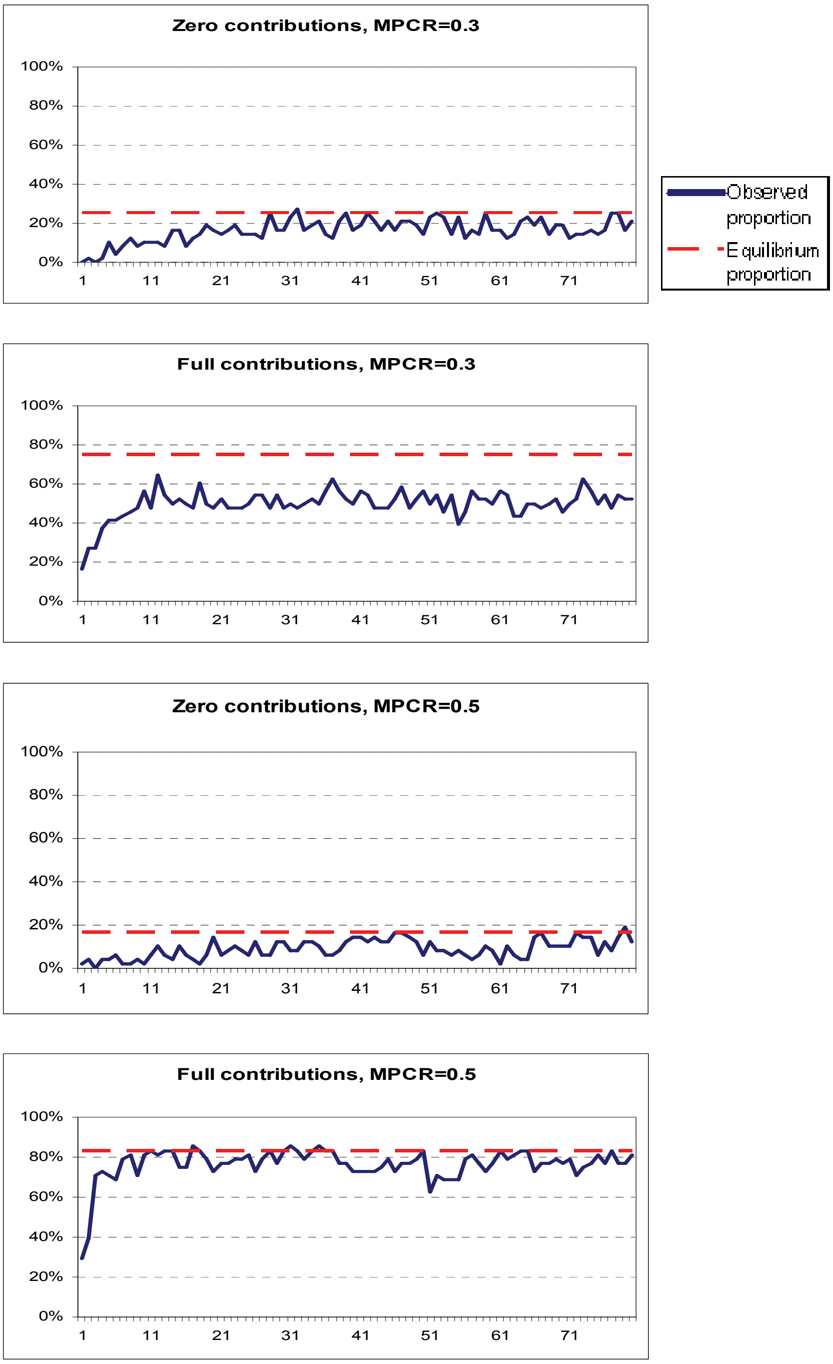


Figure 5 A

Raw frequencies per session MPCR=0.3

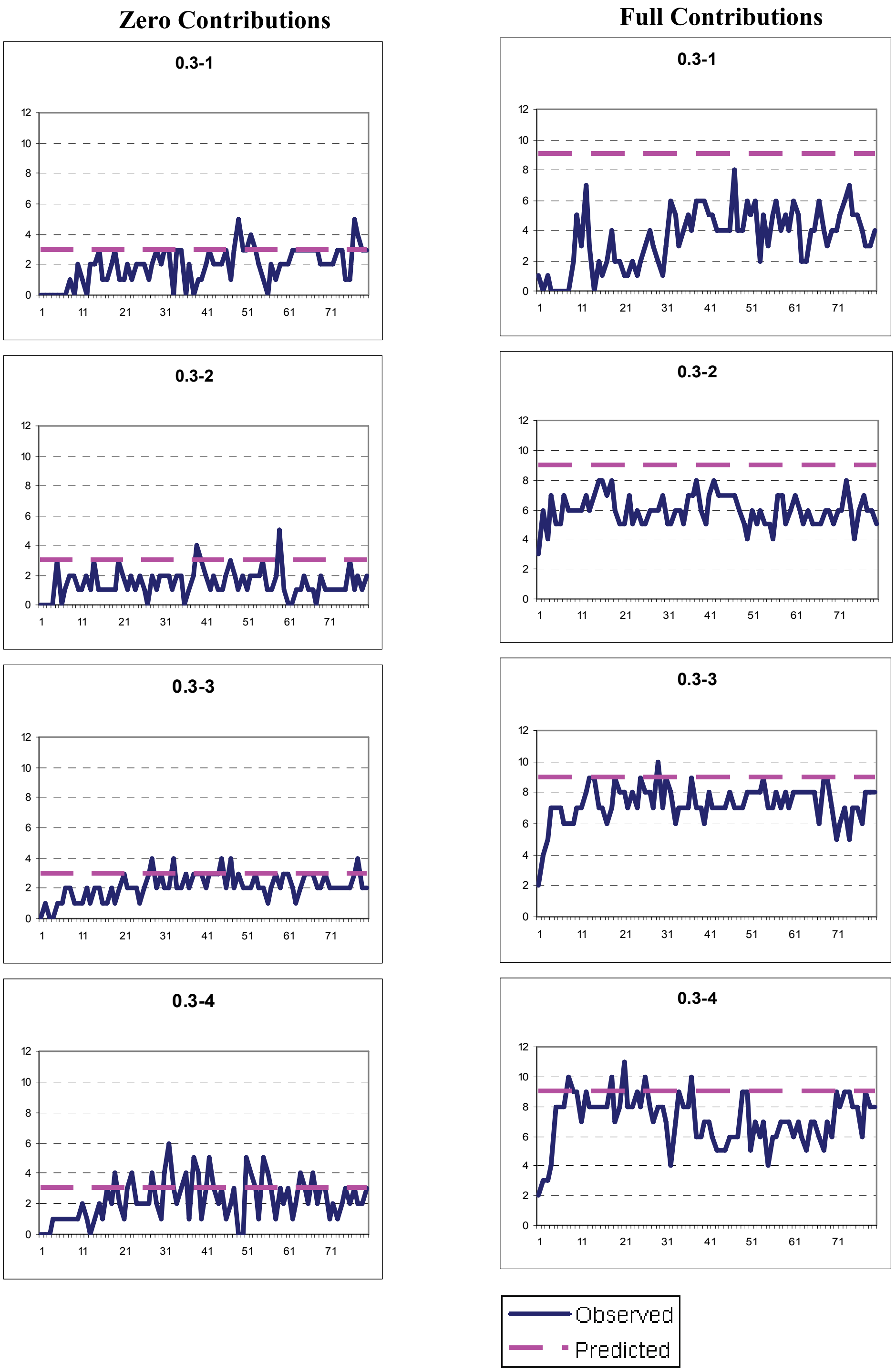
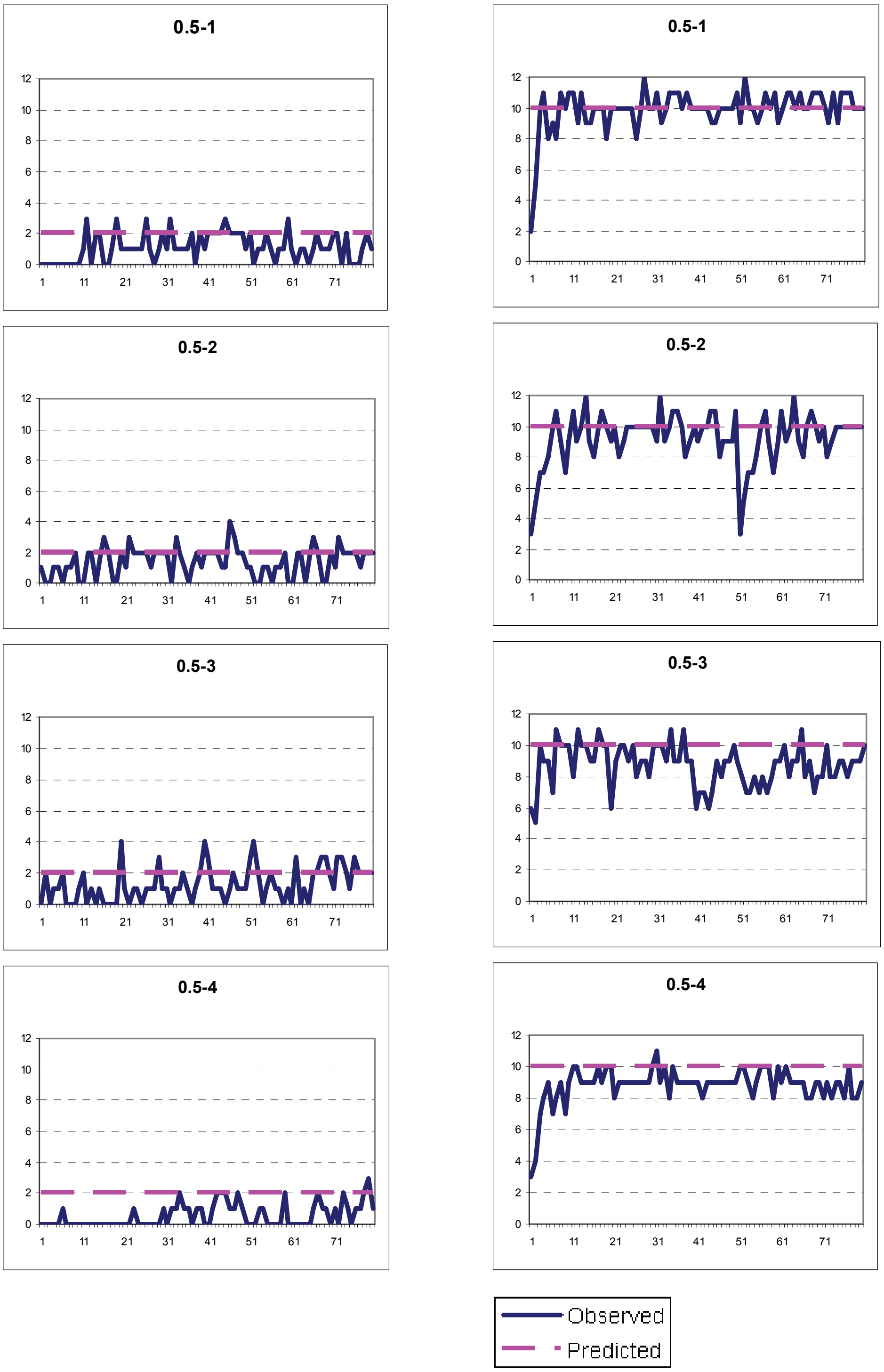


Figure 5 B

Raw frequencies per session. MPCR=0.5

Zero contributions | **Full contributions**



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introduce exclusion from the group output, rather than the group itself, again limited to the least contributor. If all contribute equally, there is nobody to exclude, hence all symmetric contribution configurations are equilibria. This form of exclusion differs from the MM since there is no contribution-based restratifcation (in fact, the authors use a partners treatment), but 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.

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The Cinambuya study differs from ours in that, group membership and group size is endogenous and, unlike in the meritocracy game, group size is not fixed, which raises the question of the cost of ostracism to those who ostracize, an issue bypassed by the meritocracy game in which everyone is assigned to group (or, if you will, social layer).

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Public good; interact with person. Same for private goods. Trust. Our result is more compelling since it shows no need for that. Only thing u know is that people are sroted. Know mpcr. 2 pieces of info and find eqm. Istory indiates maybe future but History can lock u in ineff sit since past holds on to u even if your b. changes.

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exaples of endogenous rankings.problem with putterman is a 2-sided ranking. Prefs on both sides there is no equm. Markets whre there is prefs for each other u can proof that there is no equm. If both sides have prefs over the other e.g. marriage there is no equm. The issue with the putterman paper is that prefs are mutual. Friendship group based on how ethical. Putterman: people rank each other and give each other scores and then a central agent sorts. Paper that explores experimentally endogenous ranking of subjects but so far no equm worked out. Lots of empirical studies but no eqm worked out. There might be some math connection between puttermans eqm and theirs. History makes equa very complicated. We show u don't need history for the thing to work. Yet we get efficiency. Why keep addl info about history? This is overhead. History is good because stability of past is indication of stability of future.

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a choice between entering a market and staying out, appear inconsistent with either mixed or pure
Nash equilibria. Here we show that, in this class of game, learning theory predicts sorting, that
is, in the long run, agents play a pure strategy equilibrium with some agents permanently in the
market, and some permanently out. We conduct experiments with a larger number of repetitions
than in previous work in order to test this prediction. We find that when subjects are given minimal
information, only after close to 100 periods do subjects begin to approach equilibrium. In contrast,
with full information, subjects learn to play a pure strategy equilibrium relatively quickly. However,
the information which permits rapid convergence, revelation of the individual

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min effort. groups.'
The strategic uncertainty that underlies this incentive problem can profoundly
affect behavior. Despite payoff-dominance, in VHBB's largegroup
minimum treatments A and A' subjects initially chose widely dispersed
efforts and then rapidly approached the lowest effort, ei = 1:

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Isaack smitz and wlkaer conclude: : havior we observed was a very small incidence of groups obtaining the more
efficient equilibria and a large incidence of decay to the very low levels of contributions.
For the groups that decayed, the pattern was similar to that observed
in the free-riding (dominant strategy) environment. Thus, we estabhsh

that the decay phenomenon is not caused solely by subjects learning a dominant strategy to free ride. This leads to a pessimistic conclusion that the voluntary contributions mechanism can significantly underprovide public goods in a much broader category than had been established by the dominant strategy experiments

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Our hypothesis is always at the population level. We assume that this comes due to competition. Similar example in siegel and castellan that is a pop of strikes. The question is does it correspond to the model? That it is interactive is part of the design. We know that in round 1 it does no happen, it needs to play in.

It seems to me that ks tests are very robust holt laury on risk use them by accumulating all frequences of the risk qusitonaiiroe (so that each data point is a distribution) and comparing hi and lo stake (with the same subjects, so its essentially paired). Schotter (saved) takes from the first 20 rounds and the last 20 rounds of a 60 round expt. And compares the distributions. Again, they are not inde across rounds even though subjects play against the same opponent over rounds, so this is not a source of dependence.

Kolmogorov-smirnov 1-sample test.

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The treatment effects are as e Conversely, , in 21 out of 80 rounds the null hypothesis that the *distribution of these frequencies 03 has a significantly lower median was rejected in favor of the alternate that the median of intermediate contriburions under 0.3 is in fact higher than under 0.5. (p 4,4 <0.5).* . xpected: the effect of increasing the public good payoff from low-7 to high-7 is significant: subjects in high-7 contribute more than subjects in low-7 (Mann-Whitney test with average values per session as observations, $p = 0.0495$) ;

the larger the sample size this is what what will happen.

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mean frequencs per mpcr are 57.5 vs 184.5. the test however fails to reject the null hypothesis that the frequences for positive contributions that are smaller than half the dneowment differ (p<=0.114, 2-tailed test). There frequencies are 110, 123, 83 and 52 for mpcr-0.3 and 49, 34, 69 and 68 for mpcr =05 with mean frequencies of 92 and 55, respectively.

MWW test, again with the frequency of intermed stras per session as one observation, rejects the ho that there is no difference in the frequency of contributions larger 50 and smaller than the equilibrium. (p (2-tailed)=0.029). the frequencies are 106, 96, 194 and 342 for mpcr=03, and 88, 70, 47 and 25 for mpcr=0. This difference in the frequency with which hi and low intermediate strategies are used in the two mpcrs can also be glaed from figure 2. *The "reluctant subjects" contributed substantial amounts, but short of what was categorized as a full contribution (>=98).*

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pasted Also, from the standpoint of an individual loss-averse with regard to her current wealth levels (Kahneman & Tversky, 1979), if the MPCR is low, the potential loss to a sole contributor compared to her prior endowment, *(1-MPCR)* increases as the MPCR decreases, making group contribution more "risky". In sum, even though the MPCR, within certain constrains, has no bearing on the VCM's equilibrium, it affects behavior. The MPCR does, however, affect the equilibrium in the meritocracy mechanism.