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Highlights

- Lab experiment examining individual public good contributions in competing teams
- First investigation of effect of inequality in endowments between competing teams
- Competition boosts effort up to moderate inequality but **not** at high levels of inequality
- The effect is strongest for the poor - they respond doggedly at moderate inequality
- The 'rich' disengage from competition at high inequality levels

'Doggedness' or 'disengagement'? An experiment on the effect of inequality in endowment on behavior in team competitions

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Abstract

Teams often suffer from a free rider problem with respect to individual contributions. That putting teams into competition with each other can mitigate this problem is an important recent insight. However, we know little about how inequality in endowment between teams might influence this beneficial effect from competition. We address this question with an experiment where teams contribute to a public good that then determines their chances of winning a Tullock contest with another team. The boost to efforts from competition disappears when inequality is high. This is mainly because the 'rich' 'disengage': they make no more contribution to a public good than they would when there is no competition. There is evidence that the 'poor' respond to moderate inequality 'doggedly', by expending more effort compared to competition with equality, but this 'doggedness' disappears too when inequality is high.

JEL Codes: C91, C92, D63, H41

Keywords: public goods, experiment, team competition, inequality, doggedness, disengagement

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1. Introduction

Few doubt some degree of inequality is unavoidable. For instance, if everyone received the same pay-off, independent of their efforts, there would be no incentive to make costly efforts. But can there be too much inequality? Does inequality ever discourage effort? If so, what level of inequality is optimal for the encouragement of effort? We address a specific instance of this question with an experiment. We focus on outcomes that are determined through a competition between teams, where individual contributions to team effort affect the likelihood of a team's success.

One example of this type of interaction is a competition between political parties or lobbying groups that depend on the voluntary contributions of their members to fund a campaign budget. Team sporting contests are another. Companies are similarly formed by groups of people whose combined efforts influence the likelihood of their success; and, within organizations, the tournament system of remuneration often creates such contests between sales, design, or production teams (Bandiera *et al*, 2013). These examples suggest such contests between teams are an important class of economic and social interactions.

Given monitoring difficulties, there is likely to be some individual contribution to a collective enterprise like a campaign group, a company, a sports or workplace team that is subject to the free rider problem. This is the aspect of individual behavior that concerns us because it has been argued competition between teams (or its creation) can help each team to overcome this free rider problem (see Bornstein *et al,* 1990, Bowles and Gintis, 2011, Tan and Bolle, 2007, Ishida, 2006, Guntthorsdottir and Rapoport, 2006, and Marino and Zábojník, 2004). This is an important and relatively recent insight concerning the benefits of competition. However, teams are rarely equally endowed and little is known about how this type of inequality between teams might affect this benefit. This is why our specific question is potentially important for policy. We are concerned with whether inequality of endowment between teams affects the benefit from competition for the free rider problem over individual contribution to a collective enterprise.

The question is particularly suited to experimental investigation. In part, this is because the influence of competition in this respect is often much larger than the standard rational choice models predict, suggesting competition has some additional, non-standard motivational power that can be fruitfully examined in the laboratory (see, for example, Sheremeta, 2010 for evidence on behavior in contests). In addition, there are two common but conflicting intuitions about how this specific motivational power of competition might be affected by inequality; and experiments might help settle this dispute. One intuition comes from when 'weaker' sports teams seem to perform better than expected against 'stronger' ones (as in 'Miracle', the movie version of the US ice hockey victory over the USSR in the Lake Placid Winter Olympics). The underdog is spurred by adversity, so to speak, into a special show of 'doggedness'. Alternatively, members of both teams may feel, given the level of inequality, the result is already a foregone conclusion and so all make lower contributions. This is the intuition that inequality can cause 'disengagement'.

There is some evidence of 'disengagement' in individual sporting tournaments when there is inequality (e.g. Brown, 2011 and Franke, 2012). There is also experimental evidence that investment in conflict falls in individual contests when there are differences in ability (see Fonseca 2009, Anderson and Freeborn, 2010, Deck and Sheremeta, 2012, and Kimbrough *et al*, 2014). The experimental evidence on free riding in team competitions is more mixed and focuses primarily on inequality in the number of team members. The rational choice theoretical expectation is that small teams will contribute more because the prize is worth more to each member of a small team than a big one. Kugler *et al* (2010) find contributions are boosted beyond these expectations and there is a small difference between the small and the big teams but in the reverse direction to that predicted by rational choice theory (Abbink, *et al*, 2010, have a similar result). Against this Zhang (2012), in a voter participation experiment, finds members of small groups are more likely to participate (i.e. the equivalent of contribute more) but the reverse is the case once communication within teams is allowed. Levine and Palfrey (2007), in a voting participation experiment, find evidence that as group size increases, voting falls. They also find participation increases when the election is evenly balanced, a 'competition' effect. Further, they also find an underdog effect whereby members of small teams are more likely to vote. A difference in the number of team members is one aspect in which teams may be unequal. In our experiment, in contrast, we introduce inequality through differences in the individual endowment across teams.[1]

We examine this type of inequality for three reasons. First it maps team inequality on to the more familiar form of individual endowment inequality. Second, in some settings,

[1] Bornstein *et al* (2005) introduce a different kind of inequality by making one team always the winner in the event of a tie but this has less obvious counterparts outside of committee procedures.

inequality is not or cannot be expressed through differences in numbers in each team, but it can be, and often is, manifest through differences in team endowments that are relevant in determining the outcomes of competitions. This is the case in campaigning groups where total campaign budget matters; and in sporting contests where the number of players is fixed. For instance, the cost of a player typically depends positively on that player's potential skills and where this relation is linear, the average potential skill of a team player will depend on the team's overall budget. Each player then faces a choice over how much of their potential skill, indexed in these conditions by the amount spent on his or her services, to contribute to the competition. Third, inequality in the endowment of each team does not affect the rational choice prediction of team contributions to the public good. This is potentially important for the interpretation of any differences in behavior we observe. It is well known from the individual contest literature that there tends to be over investment in conflict relative to the equilibrium prediction. In this context, if inequality affected both the rational choice equilibrium prediction and actual behavior, it would become difficult to interpret whether this arises from the change in the equilibrium or a change in the determinants of the out-of-equilibrium play. We avoid this difficulty: in our experiment, if inequality affects behavior, then it is because it influences behavior for non-rational choice reasons.[2]

The design of the experiment captures the free rider aspect of the individual effort decision via a public goods contribution problem. We examine the influence of competition between teams on these public good decisions by making a team's contribution to its public good affect its chances of success in a lottery (Tullock, 1980) contest.[3] In this we follow Guntthorsdottir and Rapoport (2006); our innovation is to introduce team inequality through the members of the 'poor' team having a smaller individual endowment than the members of the 'rich' team.

We find, like others (see Guntthorsdottir & Rapoport 2006), the existence of the Tullock contest does boost contributions to the public good as compared with the level of contributions when there is no contest; and it does so by more than standard game theory

[2] This difficulty arises in some of the 'number' inequality team contests and in those individual contests where inequality is captured by particular kinds of 'ability' differences. It is also worth noting that there is another aspect of inequality: that between members of an individual team. This aspect of inequality within a group appears to influence contributions to a group public good (e.g. see Buckley and Croson, 2006). Since, we are concerned with the effect of inequality between team resources, we deliberately avoided introducing this source of difference in behavior into our experiment by giving each individual in a team the same endowment.

[3] Savikhin and Sheremeta (2012) also study both public goods games and contests. However, they study individual decisions when the two separate games are played simultaneously, while the two games are linked in our experiment.

predicts. In this sense, competition between teams does mitigate the free rider problem within a team and so promotes efficiency in our experiment. We also find this boost is sensitive to the level of inequality between the teams. The boost occurs with equality in later periods of the game, but not when inequality is 'high'. The magic of competition in this respect, so to speak, disappears with 'high' inequality. This is largely because the 'rich' become 'disengaged' when inequality is 'high': that is, they contribute no more than they would in a simple public goods game where there is no competition with another group. There is some evidence the 'poor' respond 'doggedly' when there is moderate inequality by contributing more than they do when competition occurs between equally endowed teams. But this 'doggedness' also disappears under 'high' inequality.

Section 2 presents a model of competition, Section 3 explains the design of the experiment in detail and Section 4 gives the results. We discuss the results in Section 5 and conclude the paper in Section 6. The online Electronic Supplementary Material contains additional analysis (Appendix A) and the experimental instructions for the Moderate inequality competition treatment (Appendix B).

2. Theoretical Model

We closely follow the model of team competition presented in Guntthorsdottir and Rapoport (2006). They have a standard public goods decision that individuals in each team make. Each player i in group k composed of m players receives an endowment of $e_k > 0$ and must decide how much to invest $0 \leq x_{ik} \leq e_k$ in a public good. The remainder, $(e_k - x_{ik})$, is automatically invested in a private good. The return from the private good is 1 while the return from the public good depends on the total contribution to the public good in group k, denoted by $X_k = \sum_i x_{ik}$. Each player in group k receives a fraction, g ($0 < g < 1$ and $mg > 1$), of X_k, i.e., the marginal per-capita return (MPCR) from the public good is g. Thus the payoff to player i in group k is given by

$$V_{ik} = (e_{ik} - x_{ik}) + g\,X_k \qquad (1)$$

The Nash equilibrium in this game is for each player to contribute nothing to the public good (while the social optimum is full contribution by all players). However, this public goods decision is connected to a team competition. Two groups compete for a prize in a standard Tullock contest where the probability of success depends on relative contributions to their public goods; and this changes the equilibrium. In particular, with two groups, k and

l, competing for a prize S that is split equally amongst its m members and where each group wins the prize with a probability determined by a Tullock Contest Success Function given by (2), the pay-off to each individual is now given by (3).

$$Prob\ (Group\ k\ wins) = \begin{cases} X_k / (X_k + X_l) & \text{if } (X_k + X_l) \neq 0 \\ 1/2 & \text{otherwise} \end{cases} \quad (2)$$

$$V_{ik} = (e_{ik} - x_{ik}) + g\,X_k + [X_k/(X_k + X_l)].(S/m) \quad (3)$$

The first-order condition for player i in group k and player j in group l are respectively

$$-1 + g + \left[\frac{X_l}{(X_k + X_l)^2}\right].\left(\frac{S}{m}\right) = 0 \quad (4)$$

$$-1 + g + \left[\frac{X_k}{(X_k + X_l)^2}\right].\left(\frac{S}{m}\right) = 0 \quad (5)$$

The two first-order conditions imply that, in equilibrium the aggregate contribution to the public good must be the same: $X_k = X_l$. As long as both groups have sufficient endowments, in an interior equilibrium we have[4]

$$X_k^* = X_l^* = \frac{S}{[4m\,(1-g)]} > 0 \quad (6)$$

Without further assumptions, such as symmetry, we cannot solve for individual contribution levels. In equilibrium, they should sum to the value given by (6) but since this can be generated by a variety of individual contributions, there are multiple equilibria. Nevertheless, it is clear that the competition for a prize can raise the equilibrium contributions of groups above zero, the equilibrium in the standard public goods game (while the social optimum remains full contribution by all individuals).

Furthermore, as long as both groups have sufficient funds (as is the case in our experiment), the equilibrium group allocation is independent of the endowments of both groups. Thus, the equilibrium analysis of the interaction suggests inequality will have no effect on the public goods contributions. This enables a clean test of whether inequality has some further effect on behavior not captured by this model.

3. Experimental Design

[4] Under certain conditions, there can also exist an equilibrium where both groups contribute zero. See Chowdhury and Sheremeta (2011).

We examine whether contributions to the public good change as the equality/inequality of team endowments change across competition treatments.[5] This comparison is important but it does not necessarily reveal whether 'doggedness' or 'disengagement' as a distinct reaction to inequality has been activated. This is because, when team inequality changes, individual endowments change and there may be an effect from the altered endowment on behavior in a public goods game that explains why behavior changes with inequality. As a result, we have two kinds of treatments. There are, as just sketched, the team competition (COMP) treatments that are distinguished by the degree of equality/inequality in team endowments. In addition, there are simple public goods games (VCMs) treatments that are distinguished by differences in individual endowments (where these differences reflect those found in the team competition treatments). It is through the comparison of the team-competition contributions with the contributions under the baseline VCMs with same endowments that we examine the effect of competition after controlling for endowments. This is the pure boost from competition in each case. In particular, we perform this comparison for equal endowments and for High (see below) inequality of endowments to see whether the boost from competition is also found when inequality is High. If the boost is not found when inequality is high, we say subjects become 'disengaged' from the competition because their behavior in the competition is no different from a simple VCM with the same endowment.

3.1 Linear VCM Treatments

The simple public goods decision uses the Voluntary Contributions Mechanism (VCM) in groups of three subjects. Each subject in a group received the same endowment of tokens that could be allocated to either a private account or a group account. Subjects earned one token for each token allocated to the private account. For each token allocated to the group account, each member of the three-person group earned 0.5 tokens, i.e., MPCR = g = 0.5. Once all subjects made their contribution decisions, each subject was informed of his/her group's total contribution to the public good in that period and his/her individual earning from his/her private account and the group account.

This decision setting was repeated for 20 periods. Earnings from a period could not be carried forward to future periods. In each period, each subject received a fresh endowment.

[5] We also depart from the Guntthorsdottir and Rapoport (2006) set up by repeating the interaction 20 times (rather than 80) and by having partner rather than stranger matching. The former brings our experiment closer to the common practice in repeated public goods games and the latter is to enhance the statistical power.

Further, all members of a group received the same endowment each period. At the end of a session, tokens were converted to cash at the rate of 150 tokens to £1. To control for possible wealth effects from different levels of subject endowments, we ran 3 treatments of the VCM environment, each with different individual endowments.[6] We ran three sessions where each subject received a per-period endowment of 50 tokens and two sessions each where each subject received a per-period endowment of 20 tokens or 80 tokens.[7]

3.2 Competition with Equally-Endowed Teams (COMP(50-50))

In the competition treatment with equality, each member in a team of three members makes the same linear public goods decision as in the VCM treatments. Each member is individually endowed with 50 tokens. In addition, paired teams compete in a Tullock contest where contribution decisions in the first stage determine the probability of winning a prize of S = 120 tokens. The competitors in each Tullock contest were chosen randomly at the beginning and then kept fixed throughout a session.

In this second stage, each group was informed of their total allocation to the group account, the allocation to the group account of the competing group, the winning probabilities for each group and the winning group (one's own group or the other group) in the period. Winning probabilities were given by a Tullock contest success function given by (2).

3.3 Competition with Unequally-Endowed Teams

The three competition with inequality treatments varied the per person endowment of each team. In our High inequality treatment, members of one group in a competing pair received a per-period endowment of 20 tokens each while members of the other group received a per-period endowment of 80 tokens each. In our Moderate inequality treatment, members of one group in a pair received a per-period endowment of 40 tokens each while members of the other group received a per-period endowment of 60 tokens each. In our Low inequality treatment, members of one group in a pair received a per-period endowment of 45 tokens

[6] While previous work has looked at the issue of differing endowment sizes, they do not provide such a direct test of a "wealth effect". For instance, Isaac and Walker (1988) and Isaac *et al* (1994) also examine VCM treatments with different individual endowments. However, they also simultaneously change group size and the MPCR from the group account across treatments.

[7] We initially planned to run further VCMs with intermediate endowment levels of 40, 45, 55 and 60 (matching the full set of endowments in the COMP treatments) to examine the wealth effects in VCMs. However, for reasons that are explained later, this did not prove necessary.

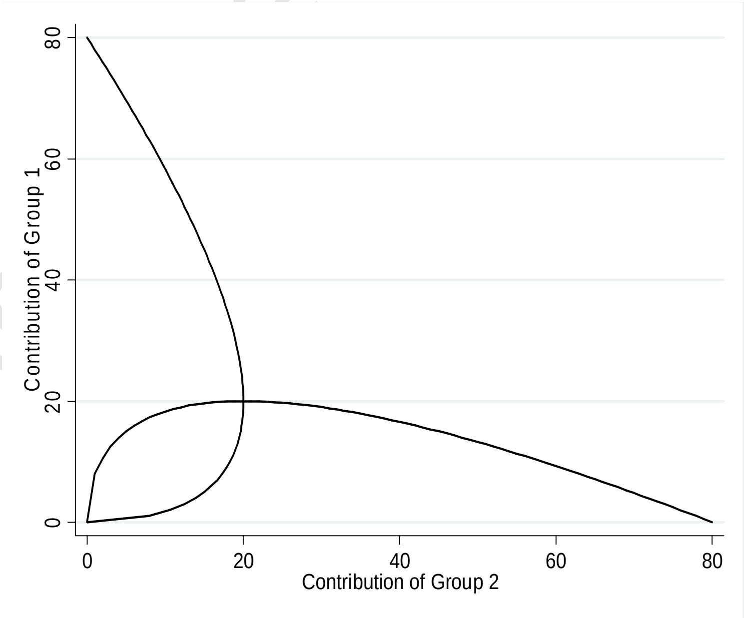
each while members of the other group received a per-period endowment of 55 tokens each. In all cases, all participants knew the endowments.

We say more about the choice of endowment and prize values below but we note now the total combined resources of both competing groups were the same in all competition treatments, i.e., 300 tokens.[8] Thus wealth is kept the same across competition treatments, only its distribution changes. For the same reason, to keep earnings comparable under the VCM control where there is no prize, final token earnings were converted to cash at the rate of 200 tokens to £1 in the four competition treatments.

We ran five sessions each of the four competition treatments, for a total of 22 groups and 11 competing pairs in each. Due to the potential effects of competition on the decisions of both groups in a pair, each comparison pair forms an independent unit of observation. We thus have data on 11 independent pairs in each competition treatment.

In the no-competition VCM treatments, zero contribution is the unique subgame perfect equilibrium in each period. Figure 1 shows the reaction functions of the two groups in the competition treatments.

Figure 1. Reaction Functions of the two competing groups



[8] Further, given our parameters, the equilibrium remains unchanged in all competition treatments. See below.

Two things to note from this are that a) the equilibrium group contribution is 20 tokens in all competition treatments and b) there is no incentive for one group to 'overbid' because the other group has contributed more than 20: i.e., neither the 'poor' nor the 'rich' should, under any set of beliefs about the other, want contributions to exceed 20. This means rational contribution in this model is always feasible for the 'poor' team, as its smallest total endowment when there is High inequality is 60. Finally, we chose S = 120 so that we would have at least one case each where the individual prize (40 tokens per group member) would be higher than, equal to and lower than the individual endowment.

3.4 Procedures

There were 27 experimental sessions conducted at the University of East Anglia (UEA). For each session, 12 to 18 subjects were recruited from the student body at UEA. Subjects were anonymously and randomly assigned to three-person groups (m = 3). The composition of these groups remained the same throughout each session, i.e., all sessions used partner matching.

At the beginning of each session, instructions were read out by an experimenter. Subjects also had a copy they could refer to at any time during the experiment. Subjects then took a quiz to ensure understanding. They could not proceed until all questions were answered correctly. Once the experiment began, subjects made decisions privately at their computer terminals. The experiment was programmed in z-Tree (Fischbacher 2007). A total of 366 subjects participated in our experiment. Table 1 summarizes our treatments and lists the number of observations in each treatment. A session lasted 45 minutes on average and each subject earned between £10 and £11 on average including a £2 show-up fee.

Table 1. Summary of Treatments

Treatment	**Endowments**	**# groups**	**# pairs**
	No Competition		
VCM(20)	20	11	-
VCM(50)	50	12	-
VCM(80)	80	11	-
	Competition Treatments		
No Inequality	50-50	22	11
Low Inequality	45-55	22	11
Medium Inequality	40-60	22	11
High Inequality	20-80	22	11
Total	**-**	**122**	**44**

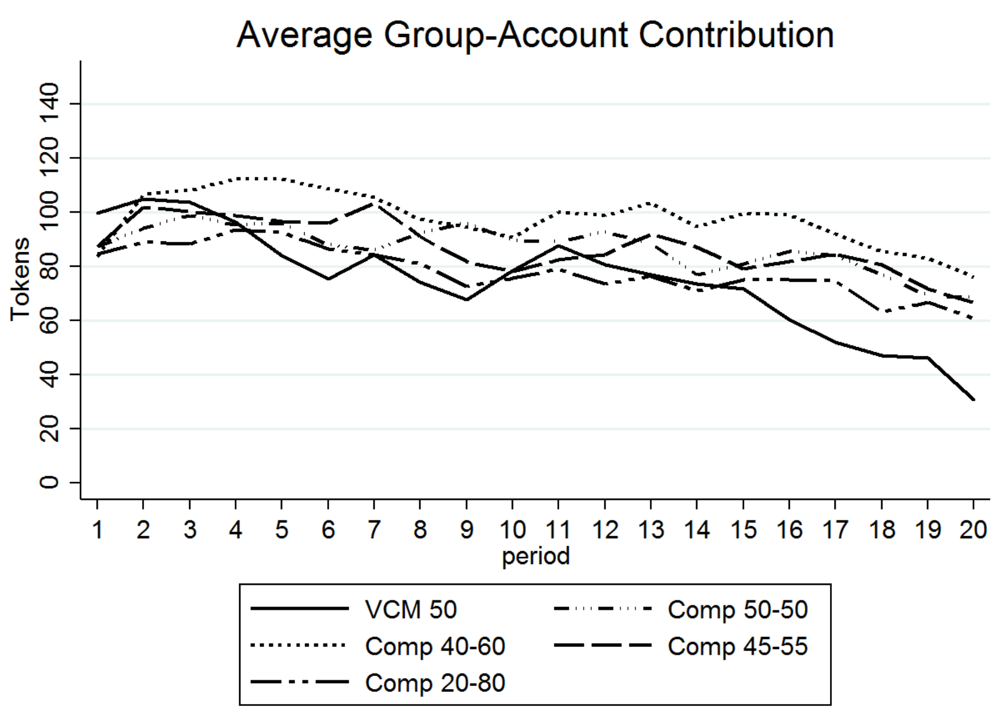
4. Results

We begin by considering the 'pure' effect of competition. This effect is isolated through a comparison of the COMP treatment with the VCM with same endowments. In particular, does the boost from competition on contributions found when teams are equal survive/change when endowments are highly unequal? We then shift to the question of the effect of inequality on behavior, given competition. We address this by comparing the COMP treatments.

4.1 Effects of competition between equals

Figure 2 presents the average group contributions over time by independent groups (12 groups) in VCM(50) and by competing pairs of groups (11 pairs) in COMP(50-50). We observe the usual pattern of contributions in the VCM (see, for instance, Fehr and Gächter 2000). They start high (here, about two-thirds of the endowment) and collapse by period 20 to about one-fifth of the group's endowment (about 30 tokens). This collapse is particularly evident in the last 10 periods of the game.

Figure 2. Average Group Contributions in VCM(50) and Pairs in Competition Treatments over time



Contributions in COMP(50-50) start at similar levels to VCM(50) and evolve in the same way until about period 10 and become notably different about period 15. Thereafter, it seems average contributions show less deterioration with equality competition than in the VCM; and groups contribute more than the equilibrium prediction of 20 tokens.

At this point, we are interested in establishing the boost from competition and not an investigation of the effects of inequality. However, for purposes of visual comparison, Figure 2 also presents the time trends of the average group contributions of the other COMP treatments. We note that patterns of contribution are similar in all COMP treatments. In particular, competition stems the decline in contributions observed in VCM(50). We leave a full analysis of the inequality treatments until later.

Table 2. Average Group Contributions by Competing Pairs

	Obs.	**Periods 1-5**	**Periods 6-15**	**Periods 16-20**	**All Periods**
VCM(50)	12	97.73	77.03	47.33	74.78
		(44.08)	(50.89)	(48.13)	(45.99)
COMP(50 -50)	11	94.28	88.00	76.83**	86.77
		(17.84)	(20.08)	(17.08)	(17.72)

Notes: Figures in parentheses are standard deviations. The unit of observation in VCM(50) is an independent group instead of a pair. A ** superscript indicates that the values are pairwise significantly different from each other at the 5% level (Wilcoxon z = -2.031, p = 0.0423).

Table 2 presents summary statistics on average group contributions by groups in the VCM and competing pairs in the equality competition treatment. We disaggregate into the initial five periods, the middle 10 periods, the last 5 periods as well as presenting data for all periods combined. While the contribution level is higher in COMP(50-50) in almost all periods, the difference is only statistically significant in the last 5 periods (p = 0.0423).

Table 3. Proportion of Zero Contributors

	Periods 1-5	Periods 6-15	Periods 16-20	All Periods
VCM(50)	0.20	0.31	0.53	0.34
COMP(50-50)	0.14	0.16	0.20**	0.16

The unit of observation is the proportion of zero contributors in a COMP(50-50) pair or VCM(50) group. A ** superscript indicates that the value is pairwise significantly different from the corresponding VCM value in the same sub-period at the 5% level (*n*=23 in each Wilcoxon test).

Table 3 reports the proportion of subjects contributing zero in VCM(50) and COMP(50-50). Although zero contribution is more difficult to interpret in this context than the standard linear public goods game, it is nevertheless illustrative of changes in behavior that occur under competition. There is a lower level of zero contributions in all sub-periods and across all periods with COMP(50-50). The difference becomes particularly pronounced in the last 5 periods when zero contributing increases greatly in VCM(50) and only slightly in COMP(50-50). This suggests there is a general influence on behavior from competition. It does not yield a statistically significant difference in average contributions in the first 15 periods, but as zero contributions jump and contributions generally drop during the last 5 periods of the VCM, the difference with respect to contributions when there is competition becomes significant. We summarize this pure boost from competition in Result 1.

Result 1: *Competition under equality reduces the incidence of zero contributions compared with the VCM, this is most marked in the last 5 periods with the result that average contributions to public goods are also higher under competition in the last 5 periods.*

4.2 Effects of competition between unequals: the case of High inequality

Figure 3A presents average contributions of the ‘poor’ and the ‘rich’ in COMP(20-80) and the relevant comparison without competition, respectively, of average contributions in VCM(20) and VCM(80). Figure 3B compares the average aggregate contribution to the public good in COMP(20-80) with the average aggregate contributions in VCM(20) combined with VCM(80).

Figure 3A: Average Contributions of `Poor' and `Rich' in Comp(20-80) and the Relevant Comparisons without Competition, VCM(20) and VCM(80).

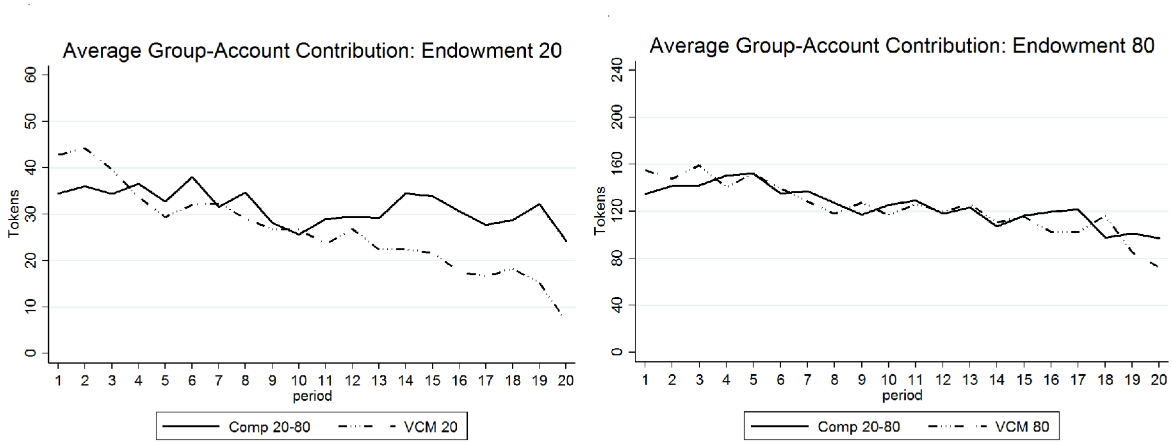


Figure 3B: Average Aggregate Contribution in COMP(20-80) with Combined VCM(20)-VCM(80)

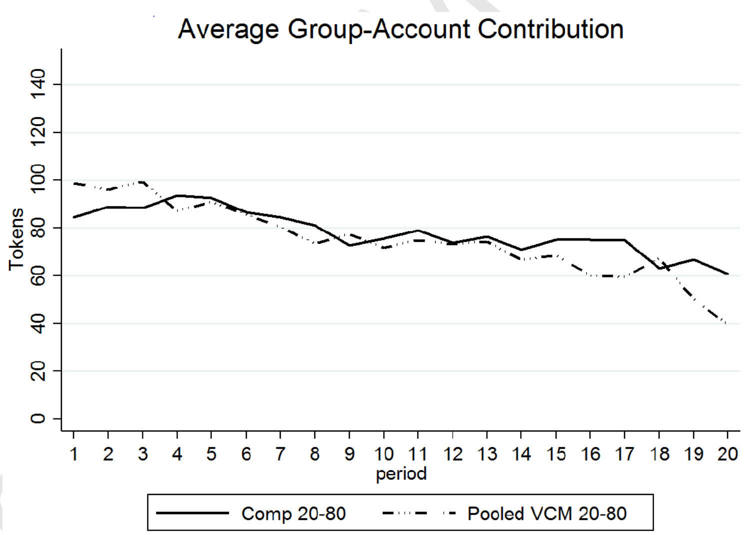


Figure 3A shows the contributions of the 'poor' in COMP(20-80) stay steady over time, unlike in VCM(20) where contributions decline steadily over time. However, the patterns of contributions of the 'rich' in COMP(20-80) are indistinguishable from contribution patterns in VCM(80). Statistical tests confirm these impressions. There is weak statistical evidence of a boost in contributions from competition among the 'poor' in the last 5 periods relative to VCM(20) [28.73 vs. 14.93, n = 11, *p*=0.094]. There is no evidence the behavior of the 'rich' is affected by competition [last 5 periods 107.47 vs. 85.65, n = 11, p=0.694].[9]

The latter is important because the 'rich' make larger contributions than the 'poor' and so exercise a disproportionate influence on total contributions. Figure 3B suggests that aggregate contributions in COMP(20-80) are not very different from contributions in a typical VCM(20)-VCM(80) combination. Tests show that there is no significant difference in total contributions in COMP(20-80) as compared with a VCM(20) combined with a VCM(80).[10] In other words, the boost from competition found under equality in COMP(50-50) compared with VCM(50) has disappeared.

Table 4 contrasts the proportion of zero contributors among the 'poor' in COMP(20-80) with VCM(20); and the proportion among the 'rich' in COMP(20-80) with that in VCM(80). The only significant difference is, once again, among the 'poor' in the last 5 periods. This reinforces what has been said before: the behavior of the 'rich' under competition with High inequality is indistinguishable from that of the behavior of people with the same endowment in a simple VCM.

Table 4. Proportion of Zero Contributions: Comparing Poor and Rich Comp 20-80 with VCM 20 and VCM 80

Treatment	Periods 1-5	Periods 6-15	Periods 16-20	All Periods
VCM 20	0.19	0.33	0.52	0.34
'Poor' Comp 20-80	0.24	0.30	0.30**	0.28
VCM 80	0.13	0.21	0.29	0.21
'Rich' Comp 20-80	0.07	0.13	0.21	0.13

A ** superscript indicates that the value is pairwise significantly different from the corresponding VCM value in the same sub-period at the 5% level (n=22 in each Wilcoxon test).

Result 2: *The boost from competition may still be present in the behavior of the 'poor' under High inequality. It is evident in a lower proportion of zero contributors and weakly so in terms of total contribution in the last 5 periods. However, there is no effect on the behavior of the 'rich' from competition when inequality is High. As a*

[9] There are no significant differences (at the 10% level) in any of the other sub-periods for the 'rich' and the 'poor'.
[10] For the combined VCM, groups from VCM(20) and VCM(80) were matched using three different random matching protocols. Standard deviations and statistical tests were qualitatively similar across the three matching protocols.

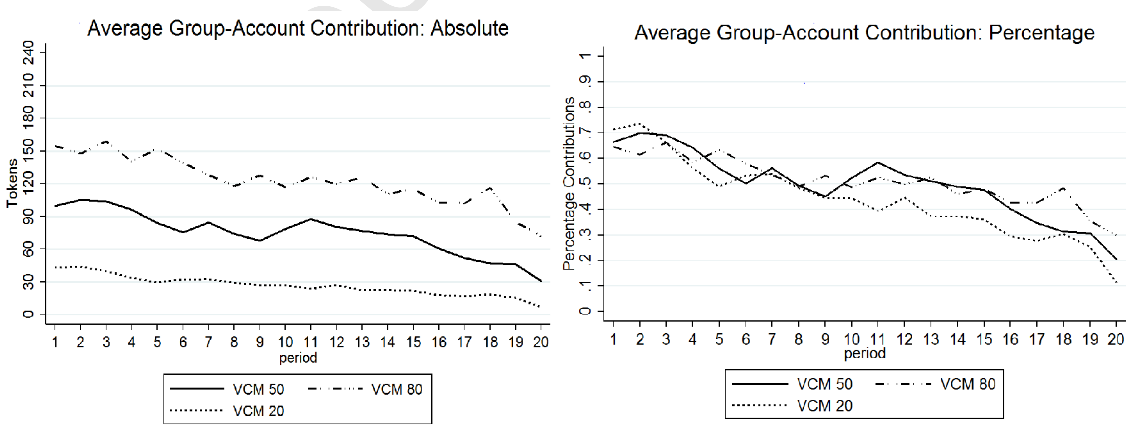
consequence of the latter, the boost to aggregate contributions from competition disappears when inequality is High.

This result suggests the 'rich' become 'disengaged' from the competition in COMP(20-80): their contributions are no different from those they would make in a VCM(80). The evidence on the behavior of the 'poor' is more difficult to interpret. In part, this is because the positive effect of competition on contributions is statistically weak. In addition, even if the effect of competition is granted, it does not necessarily represent 'doggedness' because there is no evidence from this comparison that the effect of being the 'poor' team in a competition is different to the effect of competition when the teams are equal. To explore this issue, we shift the comparison to that between the different competition treatments. To facilitate this, we begin by examining the effects of varying endowment levels revealed in the VCMs.

4.3 VCM contributions with different endowment levels

The left and right panels of Figure 4 plot, respectively, the absolute and % (of endowment) contributions in VCM(20), VCM(50) and VCM(80). They show effects from differences in endowment. However, there are no apparent effects on behavior from endowment differences when behavior is represented by contributions as a % of endowment. This is supported by statistical tests for significance in differences reported in Tables A1 and A2 in Appendix A.

Figure 4. Average Group Contributions (Absolute & Percentage) in VCM Treatments over time



Result 3: *While absolute contributions to the VCM(20), VCM(50) and VCM(80) are different, the % contributions are not statistically significantly different across these endowment levels.*

From this **Result**, we draw the more general inference that % contribution does not change with endowments over this range. As a result, it is reasonable to infer that any difference observed in the % contribution across COMP treatments reflects something other than a behavioral response to differences in endowment. This is so for the endowment levels studied above: 20, 50 and 80. In addition, since the 40, 45, 55 and 60 endowment levels fall within the (20, 80) interval and are close to 50, it is plausible to assume that the same applies for these endowment levels as well.

4.4 The effects of inequality when there is competition: the behavior of 'rich' and 'poor'

Following Result 3, we focus on the % contributions of the 'rich' and the 'poor' and consider first the average % contributions across COMP treatments. Table 5 gives these %s disaggregated across sub-periods for the 'rich' and 'poor' respectively in each inequality treatment.

Table 5. Average Percentage Contributions in the Competition Treatments

'Rich' groups

Treatment	**Obs.**	**Periods 1-5**	**Periods 6-15**	**Periods 16-20**	**All Periods**
COMP(50-50)	11	0.63 (0.12)	0.59 (0.13)	0.51 (0.11)	0.58 (0.12)
COMP(45-55)	11	0.63 (0.18)	0.57 (0.22)	0.50 (0.29)	0.57 (0.20)
COMP(40-60)	11	0.67 (0.17)	0.60 (0.20)	0.52 (0.23)	0.60 (0.19)
COMP(20-80)	11	0.60 (0.16)	0.52 (0.18)	0.45 (0.20)	0.52 (0.16)

'Poor' Groups

Treatment	Obs.	Periods 1-5	Periods 6-15	Periods 16-20	All Periods
COMP(50-50)	11	0.63 (0.12)	0.59 (0.13)	0.51 (0.11)	0.58 (0.12)
COMP(45-55)	11	0.67 (0.22)	0.60 (0.26)	0.54 (0.25)	0.60 (0.23)
COMP(40-60)	11	0.73 (0.21)	0.76 (0.27)	0.67 (0.28)	0.73 (0.23)
COMP(20-80)	11	0.58 (0.25)	0.52 (0.30)	0.48 (0.29)	0.53 (0.25)

Notes: Figures in parentheses are standard deviations.

Although the 'rich' contribute on average less as a % of their endowment in each sub-period when there is High inequality, this difference is not statistically significant. In fact, using Mann-Whitney tests, none of the pairwise treatment comparisons is statistically significant in each sub-period. The 'poor' contribute on average the highest % of their endowment in COMP(40-60) in all sub-periods and the lowest % in COMP(20-80). The 'poor's' % contribution is weakly statistically significantly higher in COMP(40-60) than COMP(50-50) in the first 5 periods ($p = 0.071$) and their contribution is significantly lower in COMP(20-80) than COMP(40-60) in the middle 10 periods ($p = 0.053$) and overall ($p = 0.053$).[11] This suggests Moderate inequality <u>may</u> produce some 'doggedness' (that is, a response greater than when there is equality in competition) but this disappears under High inequality. We check whether these differences in the behavior of the 'poor' yield any statistically significant difference between their average behavior and that of the 'rich' in these (or any sub periods) of the various COMP treatments. They do not (see Table A3 in Appendix A). Given the earlier noted fall in average % contributions of the 'rich' in COMP(20-80), this is not so surprising.

There is also support for differences in behavior of the 'poor' in the analysis of *individual* % contributions. Table 6 reports panel random effects regressions on % individual contributions.

[11] None of the other pairwise treatment comparisons for 'poor' groups is statistically significant at the 10% level in any of the sub-periods.

Table 6. Individual Percentage Contributions of the 'Poor' and the 'Rich': All Periods

<u>Dependent Variable</u>: Individual percentage contribution in each period

Independent Variables	**'Poor'**	**'Rich'**
Lagged Own Percentage Contribution	0.78*** (0.04)	0.75*** (0.05)
Lagged Deviation from Average Pct Contribution of Others	-0.32*** (0.03)	-0.21*** (0.04)
Lagged Percentage Contribution of Competing Group	-2.47 (2.76)	-1.05 (2.81)
Lagged Win	-0.22 (1.54)	-0.80 (1.52)
COMP(45-55)	-1.82 (1.70)	-1.01 (2.04)
COMP(40-60)	4.30** (1.86)	0.44 (2.03)
COMP(20-80)	-3.16 (2.17)	-2.34 (1.85)
Period	-0.46*** (0.08)	-0.40*** (0.08)
Female	-2.42* (1.36)	-0.98 (1.82)
International Student	-3.20** (1.51)	-4.11** (1.89)
Experienced	-3.21** (1.52)	-0.60 (1.83)
Age	0.15 (0.16)	0.04 (0.15)
Constant	20.73*** (4.91)	22.43*** (5.93)
Observations	3135	3135

* p < 0.10, ** p < 0.05, *** p < 0.01. Random effects panel regression model with std. errors clustered on independent (44) pairs in parentheses. Experienced subjects are those who have participated in *more than 3* economics experiments prior to this one.

The individual regressions in this table control for the standard variables in the public goods (for instance, Sefton *et al* 2007) and contest literature (for instance, Sheremeta, 2011 and Dechenaux *et al*, 2014) found to influence contributions: lagged contributions, deviations from average contributions and lagged wins. They also control for the time trends evident in the contributions. The omitted treatment is COMP(50-50). The coefficient on the COMP(40-60) dummy is positive and significant in the equation for the 'poor': that is, there is a boost from Moderate inequality as compared with Equality. The coefficient on COMP(20-80) is negative for the 'poor' and while not significant (so cannot be distinguished from Equality), it is statistically significantly different from the coefficient on COMP(40-60) [post-regression Wald test, p=0.004].[12] So, the 'doggedness' among the 'poor' induced by Moderate inequality disappears under High inequality. We also note there are no treatment effects for the 'rich'. The coefficient on the COMP(20-80) dummy is negative for the 'rich', but not statistically significant.[13]

We next investigate if the boost in percentage contributions of the 'poor' under moderate inequality is driven by a reduction in the proportion of zero contributors. Table 7 presents the proportion of zero contributors among the 'poor' in the inequality treatments in all sub-periods. For purposes of comparison, it also presents the corresponding proportion in Comp(50-50).

Table 7. Proportion of Zero Contributors among the 'poor'

	Periods 1-5	**Periods 6-15**	**Periods 16-20**	**All Periods**
COMP(50-50)	0.14	0.16	0.20	0.16
COMP(45-55)	0.10	0.13	0.19	0.11
COMP(40-60)	0.06	0.09	0.19	0.14
COMP(20-80)	0.24	0.30	0.30	0.28

As before, we find the increase in contributions by the 'poor' in COMP(40-60) relative to groups in COMP(50-50) is driven by a reduction in the number of zero contributors. The proportion of zero contributors is significantly lower in COMP(40-60) than

[12] The coefficient of Comp(40-60) is also significantly higher than that of Comp(45-55) [post-regression Wald test, p = 0.005].
[13] To further investigate treatment effects on individual contribution decisions, we performed two robustness checks. First, we examined the models in Table 6 with the 1-period percentage change in contributions as the dependent variable. The results from this robustness check are qualitatively the same as those reported in Table 6. Second, we examined the cumulative distribution of average absolute individual contribution by treatment in three comparisons: VCM(50) vs. COMP(50-50), VCM(20) vs. 'Poor' COMP(20-80), and VCM(80) vs. 'Rich' COMP(20-80). We also examined the cumulative distribution of average percentage individual contribution by treatment of all COMP treatments. Visually and statistically there are no significant differences in cumulative distributions across these comparisons.

in COMP(50-50) in periods 1-5 (p = 0.031) and in periods 6-15 (p = 0.074). Further, the proportion is lower in COMP(40-60) than in COMP(20-80) in periods 1-5 (p = 0.002), in periods 6-15 (p = 0.022) and over all periods (p = 0.023).[14]

> **Result 4:** *Moderate inequality when there is competition significantly reduces the proportion of zero contributions by the 'poor' and boosts their overall % contribution relative to competition under Equality. This reduction and boost relative to Equality disappears under High inequality.*

4.5 Optimal inequality for absolute contributions

Result 4 suggests, from a social welfare perspective, COMP(40-60) might be the best arrangement because, with the 'doggedness' of the 'poor' in this treatment, total contributions might be higher under the Moderate inequality of COMP(40-60) than any other. Table 8 gives the absolute level of contributions by treatment, as this is what matters for welfare and not % contributions.

Table 8. Average Absolute Group Contributions by Competing Pairs

Treatment	Obs.	Periods 1-5	Periods 6-15	Periods 16-20	All Periods
COMP(50-50)	11	94.28 (17.84)	88.00 (20.08)	76.83 (17.08)	86.77 (17.72)
COMP(45-55)	11	97.02 (21.56)	87.52 (30.33)	77.09 (34.76)	87.29 (27.43)
COMP(40-60)	11	104.60 (15.53)	99.36 (23.42)	87.13 (30.37)	97.61 (21.44)
COMP(20-80)	11	89.57 (15.46)	77.54 (19.88)	68.1 (25.00)	78.19 (17.74)

Notes: Figures in parentheses are standard deviations. The unit of observation in is an independent group.

The absolute level of contributions does rise as inequality increases and is highest in COMP(40-60), thereafter descending to a level in COMP(20-80) that is indistinguishable from what happens in standalone VCMs with endowments of 20 and 80. However, the difference between COMP(50-50) and COMP(40-60) is not statistically significant.[15]

[14] We conducted the corresponding across-treatment comparisons for 'rich' groups as well. We do not find any treatment differences, thus supporting the regression results for the 'rich'. For the sake of brevity, we do not report these tests.

[15] Aggregate contributions in COMP(40-60) are higher than in COMP(20-80) in periods 1-5 (p = 0.053), periods 6-15 (p = 0.061) and over all 20 periods (p = 0.045). We also compared the proportions of zero contributors in competing pairs across treatments. Unsurprisingly, the proportion is lower in COMP(40-40) than in COMP(20-80) in the same sub-periods. Differences across the other treatments are not significant.

Result 5: *Contributions in the aggregate are higher with Moderate inequality than with Equality but the difference is not statistically significant.*

5. Discussion

Results 1 and **2**, taken at face value, are important. It is known that competition between teams can help teams overcome the free-rider problem with respect to individual contributions within each team (e.g. Guntthorsdottir & Rapoport, 2006, and our Result 1). But competition between teams is rarely characterized by equal team resources and it is an open question whether the boost from competition generalizes to unequal endowment competitions. Result 2 suggests that it does not. The boost to public goods contributions from competition disappears when there is a High (20-80) level of inequality of endowment between teams.

There are two conflicting intuitions in the literature over how people might respond to inequality in a competition. People, particularly the 'underdogs', could become more 'doggedly' determined in the competition; alternatively people might become 'disengaged' from the competition because the result can appear to be a foregone conclusion. There is evidence for both in the experimental literature when inequality occurs along the dimension of numbers of team members in team competitions and for a fall in contributions when there are differences in ability in individual contests (e.g. Kugler *et al* 2010, Levine & Palfrey 2007 and Deck and Sheremeta, 2012). We contribute to this debate. Our experiment considers a different dimension of inequality: team resources. This is both common and has the advantage that it yields an equilibrium prediction of no change in behavior in response to a change in inequality. In particular, **Result 2** suggests the disappearance of the competition boost when inequality of endowment is High occurs because the 'rich' become 'disengaged' in a precise sense. They behave in the same way as they would when playing a simple VCM with the same endowment.

Result 4, trading on the insight of **Result 3** with respect to the invariance of % contribution to changes in endowment, is also important. It suggests the 'poor' respond 'doggedly' to Moderate (40-60) inequality but this 'doggedness' disappears under High inequality. In other words, the relationship between inequality and team effort is non-monotonic for the 'poor' in our experiment. This may explain why earlier experiments have found evidence for both types of effects from inequality: they could be sampling different portions of an underlying non-monotonic relationship between inequality and team effort.[16]

Result 5 suggests Moderate inequality (40-60) may be optimal for aggregate contributions to the public good in our experiment. There is weak evidence that total contributions are higher under competition with Moderate inequality than with equality. More clearly, if inequality grows to the high level (20-80), then the magical effect of competition disappears altogether. Of course, although it is natural for a firm concerned with profit or the designer of sporting contests to be concerned with aggregate contribution to the team public goods, there are other welfare standards. One might, for instance, assess the outcomes using a Rawlsian criterion by focusing on the absolute contributions of the 'poor'. From this perspective, it is difficult to distinguish between COMP(50-50) and COMP(40-60), but both are clearly better for the 'poor' than COMP(20-80) (see Table A4 in Appendix A). Thus, we conclude that as far as welfare is concerned, a state of competition and moderate inequality has much to commend. In comparison, competition and High inequality, as compared with competition with Equality or Moderate inequality, has no welfare advantage either in terms of efficiency or for a Rawlsian.

These are the insights when the **Results** are taken at face value. We turn now to whether the results should be taken in this way. We begin with an important qualification regarding our use of the terms 'doggedness' and 'disengagement' so as to focus on what is important about these results and then turn to how our results cohere with those in the literature. The results refer to changes in behavior in relation to team competition and its interaction with inequality of endowments. It is these changes that are important, not the interpretative glosses that come from attaching the terms 'doggedness' and 'disengagement'

[16] It may be useful to consider the degree of inequality, in this endowment sense, that can characterise real team competitions. This is relatively easy to do for sporting contests. The expenditure of Manchester United and Manchester City both topped £330m in the 2011/12 UK Premiership soccer season and there were 7 of the remaining 18 teams in the premiership whose expenditure in that season was less than ¼ of these values (i.e. they exceeded the 20-80 ratio of our High inequality treatment, see http://www.theguardian.com/football/2013/apr/18/premier-league-finances-club-by-club). The salary caps in the NFL yield much less inequality. In the 2012/13 season, the Detroit Lions had the top total salary bill of $128.7m, while the lowest salary bill was at the Oakland Raiders with $83.3m (see http://www.theguardian.com/sport/interactive/2013/jan/30/nfl-salaries-team-position#baltimore-ravens,san-francisco-49ers).

to them. These terms reflect one set of intuitions about how such changes might be explained, we find them plausible but they are not the only ones.[17]

One respect in which our results cohere with others is with respect to the coefficients in the individual contribution regressions on variables like lagged contribution and deviation from average contribution; they take on similar values as those found in other public goods experiments (see, for instance, Sefton *et al* 2007).[18] Likewise, our key baseline result (**Result 1**) that competition with equality of endowment boosts contributions to team public goods, reproduces a common result in the literature on competition between teams. Furthermore, although this is less remarked in the literature, we also appear to reproduce a feature of those results: that the boost occurs in the last part of the repeated interaction. For example, Nalbantian and Schotter (1997) report, in a related experiment, on the differences between remuneration schemes for the last 5 periods, but not on differences in earlier periods. Likewise, Erev *et al* (1993) have two observations on what is the effective contribution to the public good in their field experiment and the difference that emerges under competition is only present in the last of these observations. Similarly, although not part of their formal test, it would seem visually that the main difference under competition occurs in the later periods in Guntthorsdottir and Rapoport (2006).

This last commonality between our result and that of others is important in another respect: the interpretation of why the competition boost occurs. Another interpretation of why competition boosts contributions might be that it comes from the change in the Nash equilibrium. The Nash equilibrium on this account could be acting like a reference point that other-regarding motives build on. Since the VCM Nash equilibrium is for 0 contribution by each group and in the competition treatments the Nash equilibrium shifts to 20, one might expect to get what other-regarding motives supply in the VCM plus 20 when there is competition. The average boost across all 20 periods in our COMP(50-50) treatment

[17] For example, it has been argued in the individual contest literature that endowments have an effect on behavior through the element of 'free endowment' and through the influence of mistakes (see Sheremeta, 2011, Price and Sheremeta 2011, 2014). It is possible this or some elaboration of these ideas could explain our results. However, it is perhaps worth noting these 'endowment' effects appear not to be associated with the % of endowment invested in the contest in these works; and our results on doggedness refer to differences in the % contribution that occurs when inequality changes.

[18] The coefficients on the individual controls in these equations are also broadly consistent with what has been found in public goods studies. The only possible unusual one is the negative coefficient on the 'experienced' dummy in the 'poor' equation. It is also negative for the 'rich', but is not significant. We interpret a general negative effect as reflecting the way subjects who may have played public goods games are less likely to cooperate. Alternatively, since contributions typically fall in contests games as well when the contest is repeated, it may reflect experience of that game too.

compared to our VCM(50) treatment is just over 13, so the figure is somewhat close to the 20 difference in Nash equilibria. One piece of evidence that counts against this interpretation, however, is one might expect to see this throughout the 20 periods. Instead, the boost only occurs in the last 5 periods and it is at a higher value in these last periods: over 30 more than the VCM. The dramatic boost in the last 5 periods is difficult to reconcile with an influence from social preferences.

Furthermore, there is no evidence in the analysis of outcomes that a specific social preference for inequality aversion (see Fehr and Schmidt, 1999), which might be triggered by inequality of endowments in our experiment, has been in play. There is, for example, no significant difference in the response of the 'rich' to High inequality as compared with Equality or Moderate inequality (as one would expect if inequality aversion was underpinning behavior). In addition, in the High inequality treatment (as in all the treatments) the distribution of resources at the end of the experiment almost exactly matches the initial inequality in initial endowments (see Table A5 in Appendix A). Again, if inequality aversion had been driving our results, there should have been some reduction in team inequality over the course of the experiment.

Our specific result on 'disengagement' by the 'rich' and the disappearance of 'doggedness' among the poor when inequality of endowments is High is also consistent with a field experiment studying inequality of abilities. Erev *et al* (1993) find differences in team abilities are negatively associated with the productivity boost from competition for both the relatively 'high' and 'low' ability teams in their experiment. There is a difficulty with attributing these changes in productivity to the influence of inequality in abilities because these differences were not known to the subjects as part of the experimental design. It is possible, since it was a field experiment and there does not seem to have been any effort to prevent communication between subjects, the subjects might nevertheless have come to know something about these differences. In addition, they have heterogeneity within each team and this can affect behavior (see Rapoport and Suleiman, 1993, and Buckley and Croson, 2006, and Tan, 2008; Bartling and Siemens, 2011 do not find an effect on behavior). These factors make interpretation of their results difficult. Nevertheless, it is reassuring that in so far as inequality is playing a role in their experiment, it is broadly consistent with what we find when inequality is High.

6. Conclusion

At least since Adam Smith, economists have recognized the beneficial effects of competition in markets. The possible positive influence of competition on the free rider problem within teams is a more recent insight (e.g. see Bornstein *et al,* 1990, and Bowles and Gintis, 2011). This is an important development because the free rider problem exists to some degree in most teams and because many outcomes in economic and social life depend on competition between teams. However, teams are rarely endowed equally and, while there are conflicting intuitions about how this might affect individual contributions to the team effort, little is actually known about the influence of this type of inequality. This is the question we addressed with an experiment.

We find the boost from competition disappears when there is High inequality. This is largely because the 'rich' become 'disengaged': they behave no differently than they would in a VCM with the same endowment. We also find evidence of a non-monotonic relationship between inequality and the boost in contributions to the team public good made by the 'poor'. A moderate level of inequality raises the contributions of the 'poor' as a % of their endowment relative to equality. However, this 'doggedness' disappears when inequality becomes High.

These results suggest that while competition with Moderate inequality has much to commend it, there is nothing to be gained through competition when inequality is High.

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