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Abstract: We propose an intergroup competition scheme (ICS) to theoretically solve free-riding in team production and provide experimental evidence from a voluntary contribution mechanism (VCM) public goods game. The ICS includes an internal transfer payment from the lowest to highest contributing team proportional to the difference in group contributions. The ICS requires minimal information, makes the efficient contribution a dominant strategy and is budget balanced. These features make the ICS ideally suited to solve the moral hazard problem in team production. Our experiment demonstrates that the ICS raises contributions to almost reach optimality with appropriate parameters. We also show experimentally that the success of the ICS can be primarily attributed to the effect of higher returns and to the introduction of competition, and is not due to the introduction of potential losses or information regarding other groups.

JEL Classification code: H41, L22, C92

Keywords: team production, moral hazard, free riding, public goods, intergroup competition, voluntary contributions mechanism, economic experiments.

1. Introduction

Team production in modern economies has become so commonplace that it is now rare to come across a worker who does not work in a team. With so much of the world's production now done in teams, finding ways to increase team productivity is an important economic and managerial problem. One approach is to incentivize team members with "gainsharing" schemes (Welbourne and Gomez Mejia, 1995) that link employee benefits to team performance.

Team production with gainsharing is similar to public goods provision. In public goods provision, individuals decide which proportion of an endowment to contribute to a public good and which proportion to keep for private consumption. In team production, individuals decide what proportion of their time to use towards team production and what proportion to use for other activities (e.g., leisure and slack). Moreover, public good provision is shared by all individuals in the 'public' and with gainsharing production rewards are shared among all team members. The problem of public good provision comes from individual incentives to free ride on the contribution of others. Similarly, gainsharing can be subject to moral hazard problems; if only aggregate team output is observable, then it is impossible to identify individuals who free ride (i.e., provide less than optimal effort for the team).

The close relationship between team production and public goods provision problems means that the extensive literature on public goods provision and especially solutions to the voluntary contributions problem are applicable to team production. Indeed, incentive schemes have been proposed that offer theoretical solutions to reach efficient outcomes. These theoretical schemes include tax-subsidy incentives based on individual team member contributions. For instance, Falkinger (1996) shows that rewarding individual deviations from the average group contribution to the public good solves the free rider problem.[1] Some of the theoretical schemes have been tested and perform well in laboratory experiments (see Chen (2008) for a survey).[2] For instance, Falkinger et al (2000) shows that Falkinger's (1996) scheme is successful in a laboratory test.

Falkinger's (1996) result hinges on observing individual contributions to the public good. Similarly, in the team production literature, Alchian and Demsetz (1972) argue that principals (owners) need to monitor individual team members to solve the free riding problem. However, monitoring individuals may be too costly or infeasible in many cases.

To overcome monitoring issues, we propose a tax-subsidy scheme to solve the free rider problem with direct applications to team production. Critically, and in contrast to Falkinger

[1] Falkinger's model follows directly from the literature on private provision of public goods (Warr, 1983; Bergstrom et al, 1986; and especially Andreoni and Bergstrom 1996).
[2] Not all of the proposed solutions for public goods provision problems make sense in a team production environment. For instance, any tax-subsidy scheme that relies on messages (i.e., Groves and Ledyard, 1977) has no direct application for team production.

(1996) and others, our proposed Intergroup Competition Scheme (ICS) only requires knowledge of the total team production (or a proxy variable) so no individual monitoring is required.

Our proposed ICS works as follows. Two teams within a firm are matched against each other. Team members are compensated in part by gainsharing and in part by an internal transfer payment from the low output team to the high output team. The transfer is proportional to the difference in team output and equals the difference in output times a parameter. The transfer is equally funded by each member of the low output group and is equally shared by each member of the high output group. In the theory section (section 3) we show that, for a general class of games, parameters exist such that the optimal individual effort to maximize the team's total welfare becomes the dominant strategy and the incentive to free ride disappears. Additionally, the ICS is budget balanced when considering the two teams (i.e., the principal does not incur any costs on top of gainsharing payments),[3] requires little information (only team output) and is relatively robust to contingencies (adverse selection).

Our proposed ICS has many potential applications. For instance, the ICS easily applies to manufacturing industries that already use gainsharing for team assembly. Consider two teams within a firm competing against each other. For simplicity assume that technology is constant and output comparable across the competing teams. Suitable examples abound; for instance, it is common in manufacturing to use team production for the final assembly of products, from toys to computers (Young et al, 1993). In this context teams use the same technology (they have the same tools available) and produce exactly the same output with the same number of team members. To directly apply the ICS, assembly teams can compete in the total number of products assembled during a fixed time period (e.g., a month); in addition to the gamesharing received from the number of products assembled, the winning team would receive additional income transferred from the losing team proportional to the difference between the total number of products assembled by the two teams. Regardless of whether a team is producing more or less than the other team, team members will always prefer to assemble the maximum amount of products rather than free-ride.

There are other solutions proposed by theorists and/or used in practice to the moral hazard in the team production problem. Holmstrom (1982) solves the moral hazard problem by having the principal provide a bonus (a gainshare) to the whole team only if a production target is achieved. Dragon et al (1993) propose an inter-team tournament that extends the Holmstrom solution. Both schemes theoretically achieve the efficient outcome, but we believe our proposed ICS has several advantages. Holmstrom's solution hinges on a threshold output; if output is above the threshold

[3] Note that, strictly speaking, the ICS can work without any gainsharing. Optimality can be achieved just by setting up a system of intergroup transfers proportional to the difference in team productions.

individual agents receive a bonus, nothing otherwise. This approach is very sensitive to unverifiable agent's contingencies, in other words adverse selection. For instance, if a team member becomes temporarily less productive (e.g., gets sick) the threshold may well become unreachable and in this case the potential bonus will become ineffective to motivate effort. One could imagine that when an agent's situation changes, the threshold could be changed accordingly to restore efficiency. However, allowing for many potential contingencies that could be hard to verify by a principal (and difficult to contract) may alter the optimal threshold too often, thus jeopardizing the incentives of agents to contribute the optimal individual effort.[4] In contrast, with the ICS individuals have the right incentive to maximize team output no matter what contingencies emerge. In our example with one team member becoming less productive, the other team members would nonetheless have the identical incentive to work. The team would not achieve the highest output (if everyone could work), but team members nonetheless have the right incentive given the contingency they face.

We designed two experiments to test the performance of the ICS under controlled laboratory conditions. We examined the ICS in the well-known Voluntary Contributions Mechanism (VCM) public goods laboratory context. Experiment 1 tests the efficiency of the ICS compared to a standard control VCM. Experiment 2 isolates the various factors that change from the control VCM to the ICS situation to understand the behavioral effects of each factor. All the treatments in both experiments involve 10 repetitions of the corresponding game in a partners design. During the first 10 periods all subjects played the standard VCM. They were then assigned new partners for the last 10 periods to play in either the control (standard VCM game again) or one of the treatments.

Experiment 1 tests the standard control VCM with a marginal per capita return (MPCR) = 0.5 against a version of the ICS with a MPCR equal to 1.25. In this version of the ICS the marginal per capita return from the output, $MPCR^{OUT}$, is 0.5 and the marginal per capita return from the team transfer, $MPCR^{T}$, is 0.75. Therefore the total MPCR = $MPCR^{OUT}$ + MPCRT = 1.25. The ICS provides a higher MPCR through the potential transfer, and without having to increase the amount paid by the principal.

Over all periods, we find that the ICS increased the average contribution to the team project by over 50 percentage points compared to the control treatment. We observed a strong and typical (e.g. Andreoni 1988) end effect in the control condition with contributions declining to just 10% on average by the last period. In sharp contrast, in the ICS condition contributions started significantly higher from the first period and no end game decline occurred.

[4] Tournaments are similarly sensitive to contingencies; once a contingency happened and members of one team realize they cannot win, free riding becomes the best response strategy for them.

To better understand why the ICS affects subjects' behavior, we designed a second experiment with eight new treatments to isolate the key differences between the ICS and the standard VCM environment. In addition to focusing on the role of the MPCR, the treatments in Experiment 2 isolate the ICS's introduction of (a) additional information on the other team's total contribution, (b) a competitive element (regardless of the MPCR), and (c) potential losses.

We find that contributions increase as the MPCR in the ICS increases. This relationship is greater when the MPCR is less than 1 than when it is greater than 1, and we observe no additional jump in contributions when the MPCR becomes greater than 1. These relationships follow theoretically if subjects have other regarding preferences (discussed in section 5). We also find that introducing competition in the ICS while holding the MPCR constant also explains part of the higher contributions in the ICS. On the other hand, we find that the ICS's introduction of potential losses or the additional information it provides on another group's contributions does not explain any of the increases in contributions.

Last, we examined one final treatment in which we altered the ICS to have an external party provide the compensation to the team contributing more instead of a transfer from the team contributing less. In this treatment, that has been proposed and explored by others, the unique Nash Equilibrium predicts that one team will contribute 100% and the other team will contribute nothing. The experimental results are consistent with this prediction. Thus, the ICS proposed here with an internal transfer produces greater contributions than an otherwise identical externally funded scheme since the ICS motivates both teams to fully contribute.

2. Intergroup Competition Literature

Most of the literature on intergroup competition examines schemes where members of the winning group receive a bonus or reward paid by a third party, typically a principal. Thus, in contrast to our design, no transfer between the groups occurs under these schemes.

Rapoport and Bornstein (1987) introduced the intergroup competition (IC) paradigm to experimental economics and social psychology. They proposed a binary public goods game where two groups compete in aggregate contributions to earn a reward. The primary motivation for their setup was to examine the effect of differing endowment sizes, group sizes and game structure on contributions in environments with intergroup conflict (Rapoport, Bornstein and Erev 1989; Bornstein, Erev and Goren 1994; Bornstein 2003). This early stream of literature examined IC as an economic and societal problem (e.g., IC exacerbated inefficiencies in the Chicken game in Bornstein, Budescu and Zamir 1997).

The use of intergroup competition to achieve socially efficient outcomes emerges in Bornstein, Erev and Rosen (1990); Bornstein, Gneezy and Nagel (2002); and Gunnthorsdottir and Rapoport

(2006). Intergroup competition is shown to reduce free riding in laboratory social dilemma experiments (Tan and Bolle 2007; Reuben and Tyran 2010) and raise effort levels in a field study involving team production (Erev et al 1993).[5] However, none of the former schemes is budget balanced or makes the socially optimal contribution a dominant strategy of the one shot game.[6]

3. The intergroup competition scheme (ICS)

We first demonstrate how the ICS generates the optimal solution in the general public goods game with the voluntary contributions problem taken from Falkinger et al (2000). Consider an economy composed by m individuals with incomes y_r, with $r = 1, \ldots, m$. Individuals have preferences over private consumption c_r, and a public good G represented by a strictly quasi-concave and differentiable utility function $U^r(c_r, G)$. The public good is provided by voluntary contributions, that is, $G = \sum_{s=1}^{m} g_s = g_r + G_{-r}$. Without loss of generality it can be assumed that the price of the private consumption is equal to one and the price of the public good is P_G. Therefore, the individual budget constraint for individual r is given by $c_r + P_G g_r = y_r$. In the Nash equilibrium of this public goods game each individual maximizes his utility constrained by his own budget, and takes the contribution of all the other individuals as given. An interior solution is characterized by $MRS^r = \frac{\frac{\partial U^r}{\partial G}}{\frac{\partial U^r}{\partial c_r}} = \frac{\frac{\partial U^r}{\partial g_r}}{\frac{\partial U^r}{\partial c_r}} = P_G, r = 1, \ldots, m$. Optimality, however, is given by $\sum_{s=1}^{m} MRS^s = P_G$. It follows that the public good is underprovided in the Nash equilibrium.

Now consider two groups, A and B, with $n = \frac{m}{2}$ individuals each. The groups compete on the provision of the public good according to the ICS. Therefore for each individual i in group A the budget constraint changes to $c_i + P_G g_i = y_i + \delta(\sum_{k=1}^{n} g_k^A - \sum_{l=1}^{n} g_l^B)$. That is, δ times the difference in contributions with respect to the other group (positive or negative) is added to the individual's income. Now, $MRS^i = \frac{\frac{\partial U^i}{\partial G}}{\frac{\partial U^i}{\partial c_i}} = P_G - \delta$, therefore $\sum_{k=1}^{n} MRS^k = nP_G - n\delta$. The unique optimal Nash equilibrium, an interior solution, is achieved by making $\delta = (1 - \frac{1}{n})P_G$. Note that in the ICS solution preferences are still unobservable; the regulator just needs to know

[5] The introduction of intergroup competition on an online microfinance website has also been shown to raise pro-social lending (Chen et al 2013). This is especially interesting given that the competitive element in this study did not directly affect participants' payoffs, consistent with our result in Experiment 2 that the competitive element of the ICS, holding the MPCR constant, increases contributions.

[6] Eckel and Grossman (2005) present evidence from an experiment to test an internally funded 'tournament' intergroup competition scheme in one of six treatments to explore the role of group identity on contributions in public goods games. This scheme is budget balanced; each member of the group that contributes the most (least) cumulatively over five periods receives a bonus of $1 (pays a cost of $1). While the scheme performs quite well, obtaining an average of over 70% of the maximum contribution, players no longer have a dominant strategy and no evolutionarily stable equilibrium in pure strategies exist.

the *aggregate* contribution to the public good by each of the two groups. Falkinger's solution, however, requires knowledge of the *individual* contributions.

The same ICS can be also applied to solve the moral hazard in teams problem in Holmstrom's (1982) team production model. A team of n individuals take a costly non-observable action $a_i \in A_i = [0, \infty)$ with a private (nonmonetary) cost $v_i: A_i \to \mathbb{R}$; v_i that is strictly convex, differentiable and increasing with $v_i(0) = 0$. Let $a = (a_1, \dots, a_n) \in A \equiv X_{i=1}^{n}$. The actions taken by the n individuals determine a monetary outcome $x: A \to \mathbb{R}$ that must be allocated among them. The function x is strictly increasing, differentiable and concave with $x(0) = 0$. Finally, $s_i(x)$ is the share of the output that agent i receives. The preference function of agent i is additively separable in money and action, and linear in money. Holmstrom demonstrates the non-existence of Pareto efficient, budget balanced sharing rules.

Once again the optimal solution can be achieved by applying the ICS. We assume there are two n member teams, Y and Z, and the difference in output between the two groups multiplied by a parameter δ is either added or subtracted from each team member. Suppose the sharing rule is $s_i^K(x^K) = \frac{x^K}{n}$ $\forall i$, with $K \epsilon (Y, Z)$, i.e., team members share the output equally. The maximization problem for a member of team Y is:

$$\max_{a_i^Y} \frac{x^Y(a^Y)}{n} - v_i^Y(a_i^Y) + \delta(x^Y - x^Z)$$

Note that i gets a transfer if her group is ahead in output or pays a transfer if her group is behind. The first order condition that characterizes the optimal effort is given by: $\left(\frac{1}{n} + \delta\right) \frac{\partial x^Y}{\partial a_i^Y} - \frac{\partial v_i^Y}{\partial a_i^Y} = 0$ Following Holmstrom (1982), optimality implies $\frac{\partial x^Y}{\partial a_i^Y} - \frac{\partial v_i^Y}{\partial a_i^Y} = 0$. Hence an efficient solution can be achieved through intergroup competition if $\left(\frac{1}{n} + \delta\right) = 1$, therefore $\delta = 1 - \frac{1}{n}$.

For our experiments, we model a team production situation using the standard experimental context for public goods and free riding, the well-known and tested Voluntary Contributions Mechanism or VCM (Davis and Holt 1993). In the VCM participants have the same endowment w and are in teams of size N. In a general team production context w could be understood as time that can be either used for private enjoyment or as a productive input towards team output. In the laboratory w is simply a monetary endowment. Each individual has to decide how much of his endowment to use as an input to the public account t_i and how much to keep for himself $w - t_i$. In the VCM, inputs are combined to generate output in the following way: $a \sum_{i=1}^{N} t_i$, with $N >$

$a > 1$. Then output is then shared equally among the N group members. [7] The payoff therefore of player i under a VCM is given by:

$$\pi_i = (w - t_i) + \frac{a}{N}\sum_{j=1}^{N} t_j$$

With $\frac{\partial \pi_i}{\partial t_i} = -1 + \frac{a}{N} < 0$ and under the usual assumptions, the dominant strategy for each individual is to free ride ($t_i = 0\ \forall i$). However, maximum efficiency occurs when each individual agent uses her entire endowment as an input, $t_i = w, \forall i = 1, \dots, N$.

Again, consider two N member teams, denoted A and B. Further, let the difference in aggregate inputs between the two groups be multiplied by a parameter δ. This product is then subtracted from the payoff of each member of the team with the lower aggregate contribution[8] and added to the payoff of each member in the team with the higher aggregate contribution. Participants will not only receive the gainsharing given by the marginal per capita return from the team output, $\text{MPCR}^{\text{OUT}} = \frac{a}{N}$, but will also receive an additional marginal per capita return from the transfer, $\text{MPCR}^{\text{T}} = \delta$. Formally, the payoffs of team A member and a team B member are:

$$\pi_i^A = \left(w - t_i^A\right) + \frac{a}{N}\sum_{j=1}^{N} t_j^A + \delta\left(\sum_{j=1}^{N} t_j^A - \sum_{j=1}^{N} t_j^B\right)$$

$$\pi_i^B = \left(w - t_i^B\right) + \frac{a}{N}\sum_{j=1}^{N} t_j^B + \delta\left(\sum_{j=1}^{N} t_j^A - \sum_{j=1}^{N} t_j^B\right)$$

In this case, $\frac{\partial \pi_i^K}{\partial t_i^K} = -1 + \frac{a}{N} + \delta$ with $K \in (A, B)$. If $\delta + \frac{a}{N} > 1$, then $t_i^K = w$ becomes the dominant strategy. Regardless of the inputs of anyone else, it is always in an individual agent's best interest to use all of her endowment for team production. This prediction for a laboratory setup only requires experimental subjects to understand the mechanism and prefer more money to less. The unique Nash equilibrium requires all players to contribute the maximum amount, so no transfers will occur in equilibrium. That is, the VCM based ICS combines gainsharing, given by MPCR^{OUT}, with a tournament in which the bonus depends proportionally on (and is funding according to) output differences. In equilibrium no bonus is paid, but team members still receive a share of the gains. The appendix shows that the VCM based ICS can be trivially extended to any number of teams and to any team size.

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[7] In a gainsharing team production scheme the principal would distribute part of the profits generated by output to the team, not necessarily all of it.

[8] Output is simply a multiplied by the aggregate contribution.

4. Experiment 1: Testing the ICS

4.1. *Experiment 1 Design*

To test the efficiency of the proposed ICS, Experiment 1 examines a control (C) treatment with the MPCR=α/N<1 so no contribution is the dominant strategy, and an ICS treatment (ICS_dom) where the MPCR= δ+α/N>1 so full contribution is the dominant strategy of the one-shot game.

Every treatment has two stages. In Stage 1 (S1) all subjects played a standard "partners" VCM public goods game (Andreoni 1988). Subjects were randomly and anonymously assigned to groups of $N = 4$ and played the same game with the same partners for 10 periods. In Stage 2 (S2) subjects were randomly and anonymously assigned *new partners*. In the control treatment subjects played another 10 periods of the VCM game. In ICS_dom subjects played a 10 period intergroup competition game. Full contribution is the unique Subgame Perfect Nash Equilibrium (SPNE) of the repeated game in ICS_dom. The order of events is the following:

Order of Events

Condition	**Stage 1** (10: periods w/same partners)	**Between Stages**	**Stage 2** (10 periods w/same partners)
Control C	Standard VCM	assigned	Standard VCM
ICS_dom	Standard VCM	new partners	ICS_dom

Having all subjects initially play the same Stage 1 VCM game establishes a baseline level of contribution for all subjects that provides greater precision for estimating treatment effects. With this design, we estimate various versions of the following difference-in-difference (DD) model:

(1) $$y_{i,s} = \beta_0 + \beta_1 * S2_i + \beta_3 * ICS\_dom_i + \lambda * S2_i * ICS\_dom_i + \varepsilon_i,$$

where $y_{i,s}$ is subject *i*'s contribution in Stage *s* ($s = 1$ or 2) to the public good that will be either his average contribution over all ten periods of the stage or for a specific period within the stage. $S2_i$ is a dummy variable indicator for Stage 2 so β_1 estimates changes that occur when the 10 period VCM game is repeated in the control. ICS_dom_i is a dummy variable indicator for the ICS_dom treatment so β_2 estimates any baseline difference in contributions between subjects in the VCM and the ICS treatment during Stage 1. Most importantly, λ is the DD estimator measuring how subjects' contributions in the ICS_dom treatment changed from the VCM game in Stage 1 to the ICS treatment compared to how subjects' contributions changed in the control treatment when subjects repeated the VCM game.[9]

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[9] In addition to the greater precision, including S1 provided additional earnings that would minimize the risks of potential bankruptcy from potential losses in S2 in the intergroup competition conditions. No subject in ICS ever came close to going bankrupt; the lowest balance a subject ever experienced at any time in ICS was $15.00.

Procedures: One-hundred and twenty subjects participated in Experiment 1.[10] Upon arrival, subjects were randomly assigned seats in private cubicles with partitions to prevent subjects from seeing or interacting with each other. Once all subjects were seated, they were given the Stage 1 instructions. The instructions informed subjects that there would be two stages in the experiment. No further information on S2 was given during S1. After reading the S1 instructions, subjects answered a series of questions to ensure they understood the task, and then played a 10 period partners VCM (Andreoni 1988) with an MPCR of 0.5 (α/N=0.5). Subjects were randomly matched into groups of four for S1 and were informed that they would remain in the same group throughout S1. Subjects were given an endowment of 100 cents each period and could contribute between 0 and 100 cents to a neutrally framed "project" in each period. At the end of each period subjects received feedback on four pieces of information: their contribution, their group's aggregate contribution and their income that period, and their income from all periods.

At the completion of S1 subjects were given instructions for Stage 2. In S2 subjects were rematched randomly into new groups of four which they remained in throughout S2. Each subject was informed that none of the participants in her S1 group would be in her S2 group. In the ICS treatment, subjects were also informed that their group was randomly matched to another group. After the S2 instructions, subjects were given review questions regarding S2.

In the control (C), subjects' payoffs and feedback in S2 were determined identically to S1. In ICS_dom, subjects' payoffs in S2 also depended on the difference in aggregate contributions between their group and the group that they were matched with; each member of the group with the higher contribution received 75 percent of the difference in group contributions while each member of the group with the lower aggregate contributions had their income reduced by 75 percent (δ = 0.75) of the difference in group contributions. In the event that both groups had equal contributions, no money was transferred. Feedback in ICS_dom also included the aggregate contribution of the other group and the difference in aggregate contributions between their group and the other group. The experiment concluded at the end of S2.

Table 1 summarizes the key parameters for all treatments (Experiment 2 treatments will be discussed below). The first two columns show the number of subjects, sessions, groups and pairs of groups (during S2) in each treatment. The next three columns show the return from the public good ($MPCR^{OUT}$), inter-group transfer ($MPCR^{T}$) and total (MPCR) for each treatment. The final three columns show the Nash equilibrium in S2 and the average contribution for each treatment in S1 and S2, which will be discussed below.

[10] Recruitment involved the on-line email invitation system ORSEE (Greiner, 2004) inviting students to participate who had volunteered to be in the subject pool for laboratory experiments at the University of Sydney. The experiment was computerized using zTree software (Fischbacher, 2007).

Subjects received the sum of their earning across all periods in S1 and S2. On average, subjects earned $31.47. At the time of the experiment the exchange rate between the Australian and U.S. Dollar was almost exactly one to one and the minimum wage was almost $15 per hour.

Table 1: Summary of experimental treatments and average contributions

Treatment	Subjects, Sessions	Groups, Group Pairs (S2)	MPCR^{OUT} (a/N)	MPCR^{T} (δ)	MPCR = MPCR^{OUT} + MPCR^{T}	Nash Eq^ (S2)	Average Contribution	
Experiment 1							Stage 1	Stage 2
Control	48 2	12 n/a	0.50	-	0.50	$t_i = 0$	54.69	50.85
ICS_dom	72 3	18 9	0.50	0.75	1.25	$t_i = 100$	35.11	80.92
Experiment 2								
ICS0.5	72 3	18 9	0.25	0.25	0.50	$t_i = 0$	37.88	57.09
ICS0.75	72 3	18 9	0.50	0.25	0.75	$t_i = 0$	37.14	67.61
ICS0.9	72 3	18 9	0.50	0.40	0.90	$t_i = 0$	44.49	83.63
ICS1.1	72 3	18 9	0.50	0.60	1.10	$t_i = 100$	51.83	88.93
ICS1.75	32 2	8 4	0.50	1.25	1.75	$t_i = 100$	41.12	96.01
ICS1.25Noloss	56 3	14 7	0.50	0.75	1.25	$t_i = 100$	51.90	89.35
INF0.5	72 3	18 9	0.50	-	0.5	$t_i = 0$	41.07	34.73
ICS_ext	64 3	16 8	0.50	0.75	1.25	$t_i = 100$* $t_i = 0$*	39.90	64.03
Total	*632* *28*	*158* *73*						

^ Based on the standard assumptions; * The Nash Equilibrium requires members of one group to contribute everything and members of the other group to contribute nothing.

4.2. *Experiment 1 Results*

We first examine overall contributions and then subject-level period-by-period behavior. We robustly find significantly higher contributions and hence greater efficiency in ICS_dom than C.

Result 1: The ICS significantly raises contributions.

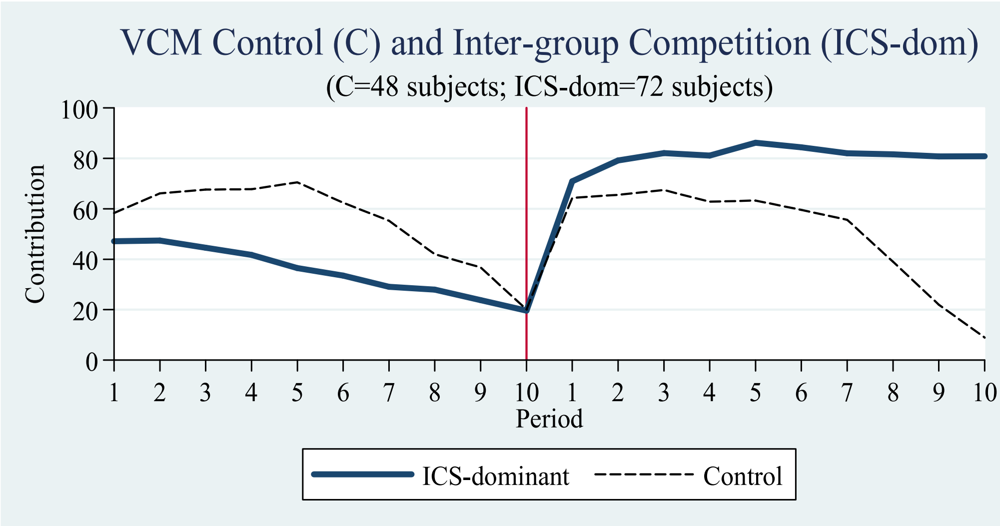
Table 1 shows that average contributions across all 10 periods in S2 was 30 percentage points higher in the ICS_dom (80.92) than in C (50.85). Using each of the 12 groups in C and 9 pairs of groups in ICS_dom during S2 for observations, the higher average contribution in ICS than C is statistically significant at the 1% level (Mann-Whitney $p < 0.001$).[11]

Figure 1 shows average contributions per period in C an ICS_dom across S1 and S2. Contributions in Period 1 of S1 show that despite identical initial conditions, subjects contributed

[11] The observations are not independent since subjects during S2 across groups would have had shared experience (been in the same groups) during S1. We econometrically address this concern with subject-level regressions comparing ICS_dom to C in this section, and then by using the session as the unit of observation in subsequent analyses. The results are robust to all specifications.

almost 11 percentage points more in C than ICS_dom. Moreover, contributions remain 10 percentage points or higher in C than ICS_dom in S1 through Period 9. The behavior in S1 suggests that, despite the sample population size (48 in C and 72 in ICS_dom), subjects were more cooperative in C than ICS_dom.[12] This difference stresses the importance of having the S1 baseline contributions to use for control in the analyses that we present next.

Figure 1: Average contributions over time: Control (C) versus ICS_dom



Average contributions per period for C and ICS_dom. S1 (S2) is shown to the left (right) of the red line.

To formally examine the ICS effects, we now present subject-level regressions with difference-in-difference (DD) analyses to estimate the change in a subject's contributions from S1 to S2 controlling for gender and period effects. The Hausman Test (pr(χ^2 = 0.999)) indicates that a random effects (RE) model is appropriate to control for individual effects in the panel data.[13] Table 2 presents the RE model estimates from Equation (1).[14] We conservatively use robust standard errors clustered at the session level. Column 1 shows estimates for period one only of each stage and Column 2 shows estimates over all ten periods. There are two observations per subject in Column 1 (one in Period 1 of S1 and one in Period 1 of S2) and 20 observations per subject in Column 2 (10 each in S1 and S2).

Result 2: The effect of ICS is immediate.

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[12] The higher average contribution in the Control is unique; average contributions during Stage 1 in the additional treatments discussed below for Experiment 2 are much closer to ICS_dom contribution levels than to the Control levels. We extensively studied potential explanations (e.g., differences in subject characteristics between the treatments and the days and times of the sessions), but could find nothing to explain the higher contributions in the control. With the large number of treatments we examined (10), we thus attribute the baseline difference in contributions to noise. In our core analyses, however, our key estimates are always difference-in-difference estimators, thus we henceforth always net out these baseline differences.
[13] We also estimated Equation (1) using Tobit Random Effects estimation but do not present these results because these estimates have similar significance levels to the RE estimates reported here and thus would not change the interpretation of the results.
[14] We also estimated FE models (available upon request) and find no qualitative differences between the FE and RE models.

Table 2: Control (C) versus ICS_dom

Dependent variable: Individual Contribution		
	(1) RE [ab] Period 1	(2) RE [abc] Periods 1-10
Constant	63.938*** (5.055)	60.442*** (4.884)
ICS_dom	-8.953 (6.271)	-10.351 (6.276)
S2	5.979 (4.562)	5.979 (4.562)
DD ICS_dom*S2	**17.785** (6.056)**	**17.785** (6.056)**
Female	-13.451** (5.047)	-5.060 (3.576)
DDD ICS_dom*S2*period2		14.618* (6.289)
DDD ICS_dom*S2*period3		19.910** (6.264)
DDD ICS_dom*S2*period4		26.604** (8.140)
DDD ICS-dom*S2*period5		39.125*** (8.535)
DDD ICS-dom*S2*period6		35.924*** (8.389)
DDD ICS_dom*S2*period7		34.806*** (8.634)
DDD ICS_dom*S2*period8		38.910*** (8.870)
DDD ICS_dom*S2*period9		54.021*** (8.029)
DDD ICS_dom*S2*period10		54.646*** (8.728)
R-square (overall)	0.119	0.470
N	240	2,400
Subjects	120	120

Models are estimated using individual random effects. Robust standard errors in parentheses; Significance levels: *** p<0.01, ** p<0.05, * p<0.1. [a] Hausman Tests: (Prob>chi^2 = 0.999) confirm RE estimation is appropriate. [b] Standard errors clustered by session. [c] In Model 2, Period dummies and Period interactions with Treatment and S2 were controlled for in the regression (output excluded).

Figure 1 shows that when the ICS is introduced a dramatic change in contributions occurs; contributions in ICS_dom are over 20 percentage points higher in Period 1 of S2 than in S1. Figure 1 suggests that this effect is not due to subjects starting over with a new group since in C contributions in Period 1 of S2 are only slightly higher than they were in Period 1 of S1.

Consistent with Figure 1, the estimates in Table 2 Column 1 show that subjects in Period 1 of S1 contributed directionally less in ICS_dom than in C (-8.95) and contributions in C were insignificantly higher in Period 1 of S2 than in S1. The key DD interaction estimate *ICS_dom*S2* ($p < 0.05$) indicates that the introduction of the ICS raised contributions immediately. The introduction of the ICS_dom scheme increased contributions in Period 1 of S2 by 18 percentage points more than contributions changed in the control treatment from S1 to S2 in Period 1.

Result 3: The ICS eliminates the decay in contributions over time.

Figure 1 shows that the difference in contributions between ICS_dom and C increased slowly through Period 7 in S2, and dramatically during the final 3 periods. This increasing difference in contributions is due to contributions in the ICS_dom not deteriorating over time as is the normal pattern in VCM experiments, seen in S1 for both treatments and seen in S2 in C. Column 2 in Table 2 presents period-by-period difference-in-difference-in-difference (DDD) estimates of the relative change in contributions in ICS_dom than C in S2 compared to the changes that occurred in S1. In addition to the estimates shown in Table 2, the regressions include controls for period and the interaction terms for each period by S2 and for each period by ICS_dom. The DDD terms *ICS_dom*S2*periodK* thus estimate the difference in contributions between ICS_dom and C *in S2* in Period K relative to Period 1 compared to the difference in contributions between ICS_dom and C *in S1* in Period K relative to Period 1. Column 2 shows that the average DDD increase is highly significant from Period 1 to all future periods. To see the large magnitude, note that during the first six periods contributions are increasingly larger in C than ICS_dom in S1 whereas contributions are increasingly larger in ICS_dom than C in S2, and over the last three periods in S2 the contributions in ICS_dom become dramatically higher than in C (essentially because contributions collapse in C while they stay high in ICS_dom).[15]

In summary, Experiment 1 shows clear evidence that the intergroup competition scheme proposed here increases overall contributions dramatically compared to the control group, and the effect is immediate and increases overtime without the endgame collapse commonly seen in public goods game VCM experiments.

5. Experiment 2: understanding why the ICS raises contributions

Full contribution is the unique SPNE of the repeated game if MCPR > 1 while contributing nothing is the unique SPNE of the repeated game when MPCR < 1. However, the MPCR > 1 in ICS_dom and MPCR < 1 in C is not the only difference between C and ICS_dom. In this section, we examine four additional factors: (i) the specific MPCR level; (ii) competition; (iii) potential for losses; and (iv) information. These factors may affect contributions if subject's preferences include (i) other regarding preferences, (ii) utility of winning or disutility of losing and loss

[15] Although the effect of ICS_dom is dramatic, average contributions in ICS_dom remain below 100 percent. This is mostly due to a small percentage of subjects in this condition who in the last period contributed nothing (6 percent) or contributed 50 (6 percent); the remaining subjects contributed on average 89%. As we show later, the other ICS conditions with MPCR = 0.9, 1.1 and 1.75 demonstrate average contributions closer to 100 percent.

aversion, and (iii) social comparisons. We discuss these factors in Sections 5.2-5.5. To test the importance of each of these factors, we ran Experiment 2.

Experiment 2 consists of eight additional treatments with 23 sessions, 128 groups and 512 new subjects. The procedures were identical to those in Experiment 1. Each session began with the same Stage 1 VCM game (with four partners together for all 10 periods). Each subject was then rematched into groups with three new partners to play the game in one of the new treatments in S2 for 10 periods. Subjects were again paid for their earnings from all 20 periods and every subject participated in only one session. All conditions and subjects' average contributions per treatment are reported in Table 1. Table 3 reports random effects regressions using *session level data as the unit of observation* clustering robust standard errors at the session level. For all analyses, each session provides two observations: one for the average contribution during Stage 1 and one for the average contribution during Stage 2. The contributions during S1 again serve as a control for any subject heterogeneity across sessions and treatments. We again estimate variations of Model 1, but now use session rather than individual level data. Because no subject participated in more than one session, the session level observations are independent.

Before discussing the new treatments, we first re-estimated the analyses comparing C and ICS_dom using the session level data to check the robustness of the individual level analyses (Table 3, Column 1). The constant term indicates the average contribution of the subjects in C during Stage 1, the Stage 2 dummy variable estimates the effect of transitioning to Stage 2 for subjects in the Control, the ICS dummy term estimates the unique effects of subjects in ICS sessions during S1, and the DD estimate of the interaction of ICS and S2 is the key estimate indicating the effect of transitioning to ICS in Stage 2 compared to staying in the standard VCM in S2 for the Control subjects. The estimates in Column 1 are qualitatively identical to those reported in Table 2 and discussed above. We again find that subjects contributed less in ICS than C during S1. Most importantly, the change to ICS in S2 (the DD estimate) results in a significant increase in contributions relative to the change in contributions in C from S1 to S2. The magnitude of the DD estimate reflects the simple averages reported in Table 1; the ICS1.25 condition increased overall contributions nearly 50 percentage points relative to the change in C.[16]

5.1 The effects of the MPCR

We showed (Section 3) that the dominant strategy of the stage game (and the unique SPNE of the repeated game) for all agents is to contribute fully when MPCR > 1 and to contribute nothing

[16] The 50 percentage point DD increase can be seen in the simple average contributions seen in Table 1; average contributions fell in C by 19.6 (from 54.7 to 35.1) while they rose by 30.0 (from 50.9 to 80.9) in ICS_dom from S1 to S2 for net DD gain of 49.6.

when MPCR < 1. This result assumed agents gain utility solely from their monetary payoffs. However, if subjects gain utility from increasing the payoffs of their team members, either by having altruistic or other regarding preferences, as widely demonstrated in the literature (e.g., Bolton and Ockenfels 2000; Fehr and Schmidt 1999) and that can help explain positive contributions in the VCM game with MPCR < 1, then the marginal utility of each additional cent contributed will exceed an agents utility from their own payoff by this additional source of utility. One can see this by letting subject i have separable utility $U_i(x)$ over her own payoff and that of others in her team when she contributes x: $U_i(x) = \text{Payoff}_{i,self}(x) + \gamma_i \text{Payoff}_{others}(x)$, $\gamma_i \geq 0$. Assuming heterogeneous utility for others, γ_i, it immediately follows that some subjects will get higher utility from fully contributing than contributing nothing even when MPCR < 1, and the percent of agents with higher utility from fully contributing will (weakly) increase with the MPCR when the MPCR < 1. For MPCR > 1, however, it remains the dominant strategy for all agents to fully contribute.

To test the effect of the MPCR on contributions, we ran five additional ICS treatments. Three treatments had MPCR < 1 (ICS0.5, ICS0.75 and ICS0.9) and two additional treatments besides ICS_dom (ICS1.25) had MPCR > 1 (ICS 1.1 and ICS1.75). In all treatments with MPCR>0.5, the $\text{MPCR}^{OUT} = 0.5$ is identical to ICS_dom, and we only varied the MPCR^{T}: $\text{MPCR}^{T} = 0.25$, 0.4, 0.6 and 1.25 in ICS0.75, ICS0.9, ICS1.1 and ICS1.75, respectively, with total MPCR thus being 0.75, 0.9, 1.1 and 1.75. In ICS0.5, we let $\text{MPCR}^{OUT} = \text{MPCR}^{T} = 0.25$ (we discuss this treatment in more detail below). To the extent that subjects heterogeneously gain utility from the payoff of others in their team, i.e., $\gamma_i > 0$, we anticipate that contributions will increase as the total MPCR increases for MPCR < 1, and that we will observe full contributions for all MPCR levels above 1.

Result 4a: Increasing the MPCR in the ICS mechanism increases contributions significantly.

Result 4b: The marginal MPCR effect on contributions is significantly greater when the MPCR is less than 1 compared to when it is greater than 1.

Result 4c: There is no additional effect of the MPCR on contributions when it is greater than or less than 1 other than through its marginal effect in Result 4b.

Figure 2 shows increasing average contributions as the MPCR in the ICS conditions increase. The solid circles show the average contribution of each ICS session during Stage 2 when the ICS was in effect. The dominant feature in Figure 2 is the sharp increase in contributions from ICS0.5 to ICS0.9 (i.e., from MPCR = 0.5 to 0.9) and a more gradual increase when MPCR is above 1.

Table 3: Average Contributions Over all 10 periods

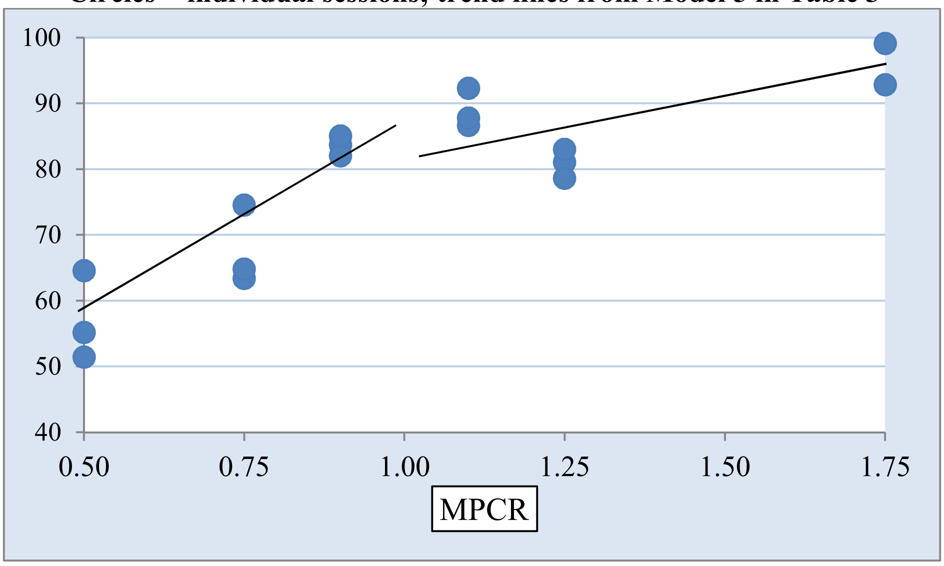
Dependent variable: Average Contribution						
Variables:	**(1) Pair-wise Robustness Check**	**(2) All ICS Robustness Check**	**(3) Tests MPCR Levels**	**(4) Tests MPCR with Dominance**	**(5) Tests MPCR with Dominance interaction**	**(6) Tests Info, No Loss and Ext**
Constant (=Ave in Control in S1)	54.694*** (1.842)	54.694*** (1.442)	54.694*** (1.463)	38.852*** (4.447)	25.801*** (4.792)	24.932*** (4.733)
Stage 2 Dummy (=Ave Shift in Control in S2)	-3.835* (2.249)	-3.835** (1.760)	-3.835** (1.787)	-3.835** (1.815)	-3.835** (1.844)	-3.835** (1.892)
ICS Dummy (=Ave Difference in ICS in S1)	-19.577*** (4.099)	-13.421*** (2.722)	-13.421*** (2.763)	-13.421*** (2.806)	-13.421*** (2.851)	-13.421*** (2.925)
DD: ICS by Stage 2 interaction	49.641*** (5.081)	40.595*** (3.809)	32.492*** (4.417)	25.876*** (3.698)	20.085*** (3.859)	19.537*** (3.940)
MPCR Effects variables:						
MPCR > 1 Dummy			17.220*** (4.640)	-2.386 (5.565)	33.056** (12.080)	36.383** (11.805)
MPCR				31.683*** (8.382)	57.786*** (9.096)	59.524*** (8.944)
MPCR by MPCR > 1 Dummy interaction					-38.574** (11.855)	-41.614*** (11.486)
Treatment Effects variables:						
ICS_No Loss Dummy						10.161 (8.683)
DD: ICS_No Loss Dummy by Stage 2 interaction						-6.372 (7.871)
INF0.5 Dummy						-13.620*** (3.374)
DD: INF0.5 Dummy by Stage 2 interaction						-2.506 (4.860)
EXT Dummy						-15.117*** (2.374)
DD: EXT Dummy by Stage 2 Dummy interaction						-0.520 (5.915)
Additional Wald Tests:						
H_0: Coefficients sum to zero MPCR by MPCR>1 + MPCR=0					*p*=0.012	*p=0.013*
H_0: Coefficients are equal DD INF0.5Dummy by Stage 2 = DD ICS by Stage 2						*p*=0.000
H_0: Coefficients are equal DD EXT Dummy by Stage 2 = DD ICS by Stage 2						*p*=0.000
R^2 (overall)	0.975	0.729	0.790	0.808	0.837	0.861
Observations (2 per session)	10	38	38	38	38	56
Sessions	5	19	19	19	19	28
Treatments	2	7	7	7	7	10
Treatments	Control & ICS_Dom	+ICS 0.5, 0.75, 0.9, 1.1, & 1.75	+ICS 0.5, 0.75, 0.9, 1.1, & 1.75	+ICS 0.5, 0.75, 0.9, 1.1, & 1.75	+ICS 0.5, 0.75, 0.9, 1.1, & 1.75	+ Info, No Loss & Ext (all treatments)

Models (1) to (6) are estimated using individual random effects estimation. Contribution data is aggregated over 10 periods into a panel of sessions with two stages, the first stage VCM game and the second stage Treatment game. Robust standard errors clustered by session in parentheses; Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 3 formally tests the MPCR effects in the ICS treatments on contributions. Column 2 first re-estimates the model in Column 1 using the data from all of the ICS treatments (ICS0.5 to ICS1.75). The estimated DD effect comparing the change in average contributions from S1 to S2 in the ICS treatments compared to the change from S1 to S2 in C remains highly significant and the magnitude of the effect remains large (over 40 percentage points).[17] Column 3 adds a dummy variable to the model that indicates whether the MPCR is greater than 1. The estimates in Column 3 indicate that the average ICS effect on contributions remains positive and significant when the MPCR is less than 1 and is significantly higher when the MPCR is greater than 1; the estimated effect of the ICS when the MPCR is less than 1 is a 32 percentage point increase in contributions, and the estimated ICS effect increases contributions by an additional 17 percentage points if the MPCR is greater than 1. However, this larger effect when the MPCR is greater than 1 may be due to a discontinuous shift at MPCR = 1 or reflect a continuous increase in the marginal impact of the MPCR on contributions that does not differ when the MPCR is above or below 1.

To test the marginal effect of the MPCR on contributions, Column 4 adds the variable MPCR to the model. Not surprisingly, the estimates show that the MPCR positively and significantly increases contributions; on average, a 0.1 unit increase in the MPCR increases contributions by 3.2 percentage points ($p<0.001$). Moreover, once we control for the marginal effect of the MPCR, the level effect due to the MPCR being greater than 1 disappears entirely. This suggests that there is no unique discontinuous level effect when the MPCR becomes greater than 1.

Figure 2: Average contributions over all 10 periods in S2 by MPCR
Circles = individual sessions; trend lines from Model 5 in Table 3



To investigate whether the marginal effect of the MPCR is different if MPCR is greater than or less than 1, Column 5 adds the interaction term MPCR by MPCR > 1 dummy to the model. The estimated negative and significant effect on MPCR by MPCR > 1 in Column 5 indicates that the marginal effect of the MPCR is significantly lower when the MPCR is greater than 1, or

[17] Note that the estimated ICS Dummy effect in Column 2 decreases from -19 to -13 when comparing the control to all ICS conditions rather than comparing the control to only ICS_dom. This suggests that subjects in ICS_dom contributed less in S1 than subjects in all other ICS treatments. Moreover, the fact that subjects in C contributed significantly more in S1 than subjects in all the ICS conditions combined (13 cents more) supports the previous discussion that subjects in C were more cooperative than typically observed in VCM games, and re-enforces the importance of S1 to control for baseline differences.

equivalently and as anticipated, indicates that the marginal MPCR effect on contributions is significantly higher when the MPCR is less than 1. Figure 2 includes the estimated slopes of the MPCR below and above MPCR = 1 from the Column 5 estimates to show these distinct effects.

We can also use the estimates from Column 5 to test whether the positive marginal effect of the MPCR on contributions when the MPCR is greater than 1 is significant. A Wald test (reported at the bottom of Table 3) indicates that the slope of the MPCR on contributions above 1 (equal to the sum of estimated effects of MPCR and MPCR by MPCR > 1) is positive and significant (slope = 19.2 = 57.8 – 38.6). Thus, while the marginal MPCR effect is smaller when MPCR is greater than 1, it remains positive and significant. Nonetheless, Table 1 and Figure 2 show that average contributions are over 96% of the maximum possible contributions when MPCR = 1.75, thus there is little room for any further effects of the MPCR beyond MPCR = 1.75. Finally, note that Figure 2 also shows that there is no discontinuous increase in contributions around the threshold MPCR equal to 1.[18]

In sum, the effect of MPCR being greater than or less than 1 is only on the slope, and as anticipated, the slope is higher when the MPCR is less than 1. The estimated effects of the MPCR within the ICS mechanism here are consistent with past studies on MPCR effects. Specifically, Palfrey and Prisbrey (1996) and Brandts and Schram (2001) varied the MPCR from zero to more than 1 and found that contributions increased as the MPCR increased but did not increase dramatically when the MPCR went from slightly less than one to slightly more than one. This evidence supports the value of ICS because ICS presents a method to increase the MPCR with all of the benefits discussed above.

5.2 The effect of competition

In addition to affecting the MPCR, subjects in the ICS may perceive their group as "winning" when their group contributes more than the other group and "losing" if their group contributes less, regardless of how much they financially win or lose; people may get utility from winning or disutility from losing that goes beyond the monetary amount. For instance, Ku et al (2005) find evidence of 'competitive arousal' consistent with people gaining utility from winning live and online internet auctions. Thus, the element of competition introduced by ICS could explain higher contributions in ICS than in the standard VCM control game.

The ICS0.5 treatment with $MPCR^{OUT}$=$MPCR^{T}$=0.25 includes the competitive element but holds the MPCR at the same level in the control at MPCR=0.5. In ICS0.5 subjects thus faced the

[18] To formally confirm the absence of an increase at MPCR = 1, using the estimates in Column 5 we tested whether the sum of the coefficients on MPCR by MPCR>1 dummy and MPCR>1 dummy was equal to zero. The Wald test (not shown) indicates there is no discontinuous change at MPCR = 1 at the 10 percent significance level (p>.10).

identical total MPCR as the control, but have the competitive ICS element and the potential for monetary losses to the other group if the other group contributes more.

Result 5: The competitive element in the ICS explains part of the higher ICS contributions.

Table 1 shows that the average contribution in ICS0.5 increased from S1 to S2 by 19.2 percentage points whereas contributions in the control condition fell 3.8 percentage points from S1 to S2. The role of competition, holding the MPCR constant, can be seen in Table 3 in Columns 4-6; the DD interaction term *ICS by Stage2* in these estimates captures the competitive role of the ICS holding MPCR constant since these models control for the MPCR effect (in other words, ICS by Stage 2 captures the DD effect of ICS0.5 compared to the control). Columns 4-6 show that the DD estimates ICS by Stage 2 are significant at the 1 percent level and indicates that the role of competition in the ICS scheme increases contributions by 20 percentage points (in the more fully specified models in Columns 5 and 6). Nonetheless, competition alone only partially explains the positive ICS effects since, as already discussed, increasing the MPCR increases contributions even further.

5.3 The effect of potential losses

Another difference between the control and ICS conditions is that subjects can potentially earn a negative payoff each round of the ICS game if, for instance MPCR > 1, then every subject on one team contributes nothing and every subject on the competing team fully contributes. To the extent that subjects in the group that contributed less to the public good in ICS perceive the resulting transfer to the other group as a loss, loss aversion (Kahneman and Tversky 1979; Tversky and Kahneman 1992) predicts that these subjects will incur greater disutility than an equally sized monetary gain. Thus, loss aversion suggests that subjects may contribute more in ICS to avoid additional disutility associated with losses. The potential for a monetary loss may also be perceived as punishment which Fehr and Gächter (2000a,b) show can motivate greater contributions to avoid punishment. Thus, subjects may have contributed more in the ICS conditions in part to avoid suffering a loss (and perceived punishment). Although losses were rare (less than one percent of payoffs were negative), suggesting the concern for losses may not have being affecting decisions, it is also possible that losses were rare because subjects were contributing more in the ICS to avoid losses in the first place. Thus, to test whether avoiding losses caused higher contributions in the ICS conditions, we ran another treatment, ICS_No Loss that was in every way identical to the original ICS_dom with MPCR = 1.25, but we removed the possibility that subjects could lose money in any period. Specifically, subjects' payoffs were bounded in each period at 0, and if a subject (or subjects) in a team would have received a negative payoff after the intergroup transfer, then we limited the transfer to avoid losses and adjusted the transfer to the group contributing more to equal the truncated amount being transferred.[19]

The last column in Table 3 presents the results. We include a dummy variable for the ICS_No Loss treatment to control for subject heterogeneity (this term estimates the different level of contributions during S1 in ICS_No Loss compared to the control). We also include a dummy variable for the interaction of ICS_No Loss and Stage 2 to estimate the DD change due to the treatment from S1 to S2 relative to the estimated change in ICS (since ICS_No Loss is also an ICS condition).

Result 6: Higher contributions in the ICS conditions cannot be explained by a concern for losses.

Average contributions during S1 in ICS_No Loss are statistically similar to those in the control, though directionally subjects in ICS_No Loss contributed a little more. Controlling for this heterogeneity, we find that the estimated DD effect of ICS_No Loss is not statistically different compared to the estimated DD ICS effect and directionally leads to a slightly smaller change in contributions on average (approximately 6 percentage points less). This can also be seen in Table 1; on average, subjects contributed an additional 45.8 and 37.5 percentage points in ICS_dom and ICS_No Loss, respectively. Thus, an identical ICS plan (both with MPCR=1.25) that removes the potential for loss (and perceived punishment) has no effect on contributions, and thus cannot explain the higher contributions due to the ICS.

5.4 The effect of information

Group identity theory (e.g., Rabbie and Horwitz 1969; Tajfel et al 1971; Eckel and Grossman 2005; Chen and Li 2009) suggests that people can gain utility if their group (in-group) does better than another group (out-group), even when there are no financial implications to doing better. Group identity theory thus suggests that part of the higher contributions in ICS treatments may be due to information about another group. To test whether the difference in the amount of information provided to subjects in the ICS treatments explains part of the higher contribution, we ran an information treatment INF0.5. In INF0.5, subjects played the same VCM in S2 identical in every way to C (i.e., same earnings calculation, same MPCR=0.5, and same own group feedback), but each group was also *paired with another group* at the beginning of S2 and subjects were given the aggregate contribution of this other group after each period identical to the information subjects were given each period in ICS. Column 6 in Table 3 presents the estimated effects. We include a dummy variable for INF0.5 (to estimate the unique effects of

[19] In ICS No Loss studied here, full contribution remains the unique Nash Equilibrium of the stage game (and the unique SPNE of the repeated game), but is no longer a dominant strategy.

subjects in INF0.5 during S1) and a dummy variable for the interaction of INF0.5 and Stage 2 to estimate the DD change due to INF0.5 from S1 to S2 relative to the estimated change in the control. The bottom of Table 3 also includes a Wald test of significance for whether the estimated DD effect of INF0.5 is different than the estimated DD effect of the ICS with the identical 0.5 MPCR.

Result 7: information alone cannot explain the higher contributions in ICS.

Table 1 shows that average contributions in INF0.5 fell 6.3 percentage points from S1 to S2. Table 3 shows that subjects in INF0.5 contributed 13.6 percentage points less than subjects in C during S1, nearly identical to the 13.4 percentage points lower contributions in S1 in the ICS conditions compared to the control. The DD INF0.5 by Stage 2 estimate indicates that the effect of introducing information only from S1 to S2 had almost the identical effect on contributions as simply repeating the identical VCM in the control; subjects in INF0.5 on average contributed 2.6 percentage points less from S1 to S2 compared to the change for subjects in the control from S1 to S2 ($p > .20$). Thus, information alone on another group's aggregate contributions cannot explain any of the higher contributions in the ICS treatments. The Wald test comparing the marginal DD effects of INF0.5 to the DD effects of ICS from S1 to S2 further supports this conclusion by showing that the introduction of the ICS in S2 significantly increases contributions compared to the (lack of) change in contributions in INF0.5.[20]

5.5 Comparison of ICS to an externally funded scheme

One of the fundamental ways in which the ICS proposed here differs from past intergroup competition literature is that our mechanism includes an internal transfer from the group contributing the least to the group contributing the most to induce a dominant strategy in which each individual fully contributes to the public good. In other proposed IC plans (e.g., Reuben and Tyran 2010) the group contributing the most is funded by a bonus at least partly paid by an outside party, and the group contributing the least does not have to pay for the bonus. In this alternative externally funded IC plan, if group A contributes more on aggregate then the payoff to members of group A and B, respectively, would be:

$$\pi_i^A = (w - t_i^A) + \frac{a}{N}\sum_{j=1}^{N} t_j^A + \delta\left(\sum_{j=1}^{N} t_j^A - \sum_{j=1}^{N} t_j^B\right) \textit{ and } \pi_i^B = (w - t_i) + \frac{a}{N}\sum_{j=1}^{N} t_j .$$

If both groups contribute the same aggregate amount than individuals receive:

$$\pi_{\mathrm{i}} = (w - t_i) + \frac{a}{N}\sum_{j=1}^{N} t_j$$

[20] In an earlier version of this paper (available upon request) we reported pair-wise comparisons of INF0.5 with C and INF0.5 with ICS0.5 that provide the identical conclusion.

In this setup, it is easy to show that the Nash equilibrium involves full contributions for all players in one group and no contributions by any player in the other group when $a/N < 1$ and $a/N + \delta > 1$, respectively. Thus, the ICS_dom treatment is predicted to provide higher overall contributions compared to an external funded IC because only one group will fully contribute when externally funded while both groups will fully contribute when internally funded.

To test this hypothesis, we ran a new treatment ICS_ext where everything is identical to ICS_dom except that the group contributing the most receives the $\delta = 0.75$ transfer from the experimenter rather than from the group contributing less. For ICS_ext, we had 64 subjects participate with 16 groups in S1, and 16 groups and 8 pairs of groups in S2.

Result 8a: The externally funded ICS increases contributions compared to the Control due to the higher MPCR.

Result 8b: Overall contributions are higher in the internally than externally funded ICS.

Result 8c: The higher overall contributions in the internally funded ICS are driven by significantly higher contributions of the group contributing less in the internally funded pairs than the groups contributing less in externally funded pairs.

Table 1 shows that the average contribution in ICS_ext increased from S1 to S2 by 25 percentage points whereas contributions in the control condition fell 4 percentage points from S1 to S2 and contributions in ICS_dom increased 46 percentage points. Similar to the other ICS treatments, Column 6 in Table 3 shows that subjects in ICS_ext contributed significantly less during S1 than subjects in the control. The estimates also indicate that once controlling for the higher MPCR effect in ICS_ext, there is no additional effect of ICS_ext compared to the control (estimated DD effect -0.5). The Wald test comparing the DD ICS_ext and the internally funded ICS DD estimates indicates that contributions increased more in the internally funded scheme ($p<.001$).

To understand why the internally funded ICS significantly increased contributions more than the externally funded scheme, we examine the contributions of the groups which contributed more and the groups which contributed less within each pair in the internally funded scheme to those groups in the externally funded scheme which contributed more and those which contributed less within each pair, respectively. For this examination, we compare ICS_ext to ICS_dom in order to have the identical MPCR across the internally and externally funded schemes. Figure 3 shows the predicted separating equilibrium behavior in groups in the ICS_ext condition. For instance, in six of the nine pairs in ICS_ext the differences in average contributions in the last period are at least 50 percentage points whereas in ICS_dom there are no pairings that exceed a difference in contributions of 50 percentage points. Figure 3 also generally shows the standard decline in contributions in the last few rounds seen in the control (Figure 1) and past VCM studies in ICS_ext among subjects in the groups contributing the lower amount in each pair, but not for the subjects in the groups contributing the larger amount.

Table 4 shows the average contribution in the last period of S2 for the ICS_ext and ICS_dom treatments for the groups that contributed the most and the least. As anticipated, there is little difference in the contributions by the groups that contributed more in ICS_dom and ICS_ext (Mann-Whitney $p = 0.318$). For the groups that contributed less, however, the ICS_dom subjects continued to contribute a relatively high amount (71.0) while ICS_ext contributions collapsed, and the difference in contributions between the groups that contributed less in ICS_dom and ICS_ext is highly significant (Mann-Whitney $p < 0.01$). In sum, the ICS_dom theoretically increases contributions to participants in both groups whereas the externally funded ICS_ext scheme theoretically increases contributions to just one group, and the experimental evidence supports this distinction.

Figure 3: Comparison of higher and lower contributing groups over 10 periods (Illustrate the separating equilibrium of the ICS_external condition)

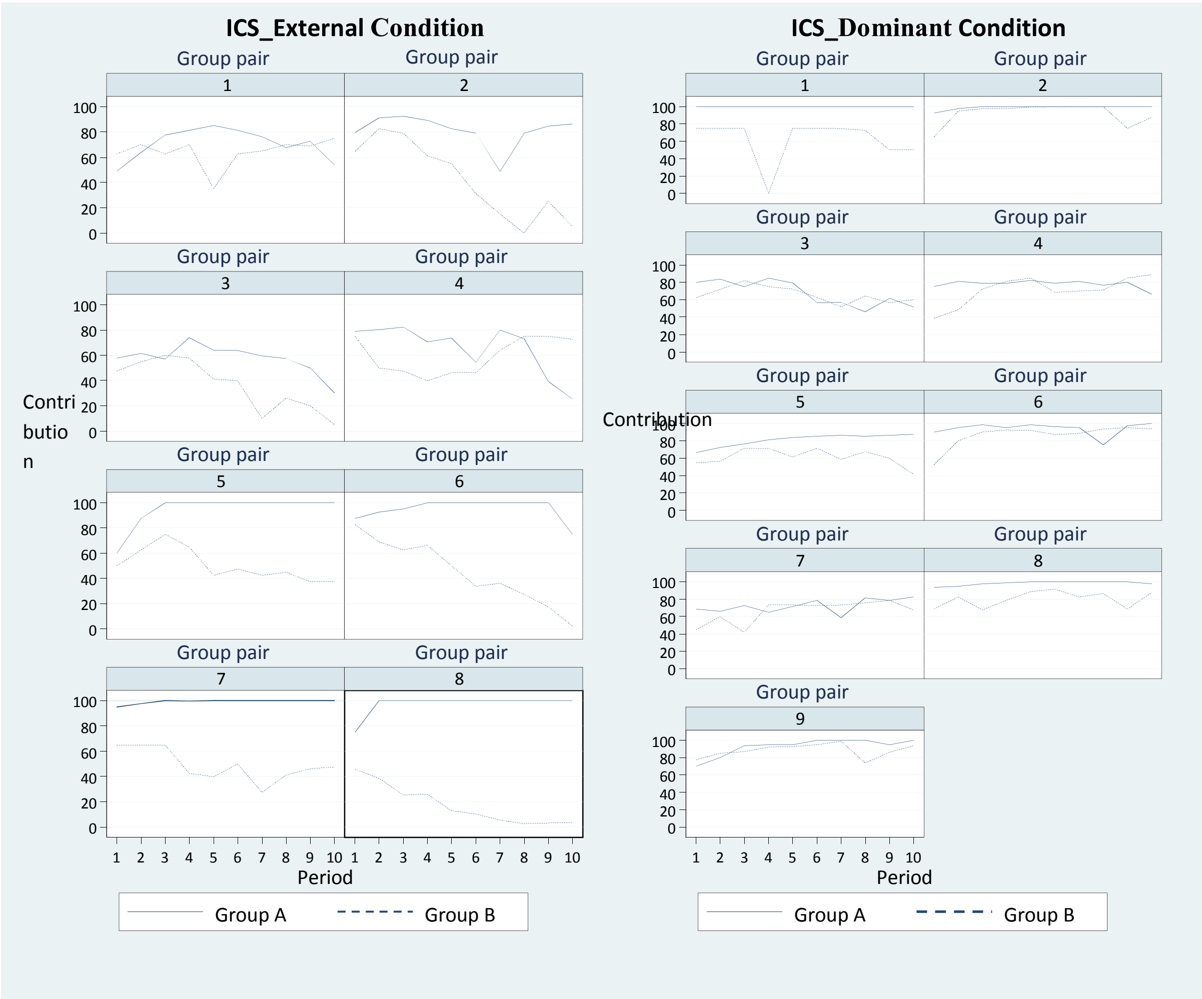


Table 4: Contributions in the last period of S2 in ICS_dom and ICS-ext:

	Group contributing the most		Group Contributing the least	
	Mean	s.d.	Mean	s.d.
ICS_dom (N=9)	90.69	13.30	71.00	20.37
ICS_ext (N=8)	79.84	23.43	22.53	21.41

5.6 Comparison to experiments examining individual bonus/penalty mechanisms

As discussed in the introduction, our proposed internally funded ICS can be derived from a solution to the team production problem that provides bonuses/penalties based on comparing individual level contributions to group level production. While our solution addresses the information and monitoring challenges of these solutions, it is nonetheless interesting to compare the efficiency of our ICS to other studies comparing individual level contributions in order to see whether our ICS sacrifices efficiency. Falkinger et al (2000) present experimental evidence that introduce a bonus/penalty with an MPCR = 1.1 (their treatment M1) that achieves 84.5% efficiency. Bracht et al (2008) provide a comparison of the Falkinger (1996) mechanism with Varian's (1994) compensation mechanism.[21] They find that both mechanisms increase contributions towards the optimum, but neither gets close to 80% efficiency. Chen's (2008) survey argues that some mechanisms (best case scenario) applied to the public goods game converge "reasonably well" to the optimal Nash equilibrium when tested in the laboratory. In contrast, the effect of the ICS is immediate. While it is difficult to compare across the experimental evidence because of differences in experimental design and subject populations, it does not appear that the efficiency of the ICS studied here (with 89% and 96% efficiency when the MPCR is 1.1 and 1.75, respectively) is any lower for similar MPCR levels in other studies.

6. Summary

In this paper we proposed a solution to the free-rider problem. In theory, with the right parameters such that $MPCR^{OUT} + MPCR^{T} > 1$, the ICS induces the efficient contribution to team production. Our experiments suggest that optimality can be obtained, and sustained. This result can be partially, but not entirely, explained by a 'taste' for competition. It can also be partially by the increasing MPCR. The higher contributions are not, however, due to either the possibility of loss or the additional information on another group's performance. In line with previous research (Palfrey and Prisbrey 1996; Brandts and Schram 2001; Tan and Bolle 2007), high contributions can be achieved with the ICS even if the combined MPCR is less than one. We found that average contributions of close to 100 percent can be achieved by an ICS with a total MPCR of 1.75. We also found that if the ICS is externally rather than internally funded, then contributions

[21] In the compensation mechanism each player offers to compensate the other for the "costs" incurred to make the efficient choice.

are lower, and are lower in a manner reflecting the theoretical prediction that in equilibrium one group fully contributes while the other group does not contribute.

In contrast with other schemes, the currently proposed ICS is budget balanced, so no money on top of a gainshare needs to be injected externally, and the internal transfer setup makes the optimal contribution a dominant strategy of the one-shot game and the unique SPNE of the repeated game without having to rely on a taste for cooperation.[22] In addition, and what seems most practical, the ICS proposed here requires little information - just the aggregate group contributions are needed - to effectively overcome the moral hazard problem in team production.[23]

[22] In theory, without imposing much structure, the ICS would also work for pure and conditional cooperators.

[23] The ICS may also be robust to sabotage (Lazear 1989); with our ICS sabotage is only profitable if substituting one unit of effort away from own group production (a loss of $MPRC=MPRC^{PG}+MPRC^{T}$) reduces the rival team's production by more than $s*MPRC^{T}$, where s is the number of units of the rival's production that is destroyed by effort devoted to sabotage. For ICS_dom studied here, this implies $s > 1.25/0.75 = 1.67$. In general, $s > 1$ will minimally be required for sabotage, so sabotage will only be profitable if the productivity of effort from sabotage exceeds the productivity of effort for own group production.

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APPENDIX

We show that the ICS results established in the text for n = 2 groups of equal size can trivially be extended to (1) any finite number of groups n ≥ 2 (A.1), (2) groups of different sizes (A.2), and (3) extended to non linear public goods games.

A.1 The ICS extended to any number of groups n ≥ 2:

For n ≥ 2, the ICS can be implemented with a balanced budget. We first demonstrate this with n = 3 groups: The payoff function for member *i* in group's A, B and C, respectively, are:

$$\pi_i^A = (w - t_i^A) + \frac{a}{N}\sum_{j=1}^{N} t_j^A + \delta\left(\sum_{j=1}^{N} t_j^A - \frac{(\sum_{j=1}^{N} t_j^B + \sum_{j=1}^{N} t_j^C)}{2}\right),$$

$$\pi_i^B = (w - t_i^B) + \frac{a}{N}\sum_{j=1}^{N} t_j^B + \delta\left(\sum_{j=1}^{N} t_j^B - \frac{(\sum_{j=1}^{N} t_j^A + \sum_{j=1}^{N} t_j^C)}{2}\right),$$

$$\pi_i^C = (w - t_i^C) + \frac{a}{N}\sum_{j=1}^{N} t_j^C + \delta\left(\sum_{j=1}^{N} t_j^C - \frac{(\sum_{j=1}^{N} t_j^A + \sum_{j=1}^{N} t_j^B)}{2}\right).$$

To satisfy a balanced budget, the transfers to/from member *i* in each group must sum to zero. This is indeed the case as the sum of the transfers:

$$\delta\left(\sum_{j=1}^{N} t_j^A - \frac{(\sum_{j=1}^{N} t_j^B + \sum_{j=1}^{N} t_j^C)}{2}\right) + \delta\left(\sum_{j=1}^{N} t_j^B - \frac{(\sum_{j=1}^{N} t_j^A + \sum_{j=1}^{N} t_j^C)}{2}\right) + \delta\left(\sum_{j=1}^{N} t_j^C - \frac{(\sum_{j=1}^{N} t_j^A + \sum_{j=1}^{N} t_j^B)}{2}\right)$$

Reduces to:

$$2\sum_{j=1}^{N} t_j^A - \sum_{j=1}^{N} t_j^B - \sum_{j=1}^{N} t_j^C + 2\sum_{j=1}^{N} t_j^B - \sum_{j=1}^{N} t_j^A - \sum_{j=1}^{N} t_j^C + 2\sum_{j=1}^{N} t_j^C - \sum_{j=1}^{N} t_j^A - \sum_{j=1}^{N} t_j^B = 0$$

To generalize, note that with n > 3 groups, if there is an even number of groups then we can arbitrarily assign groups to parings to play the ICS. If there are an odd number of groups then we can arbitrarily choose three groups to play the ICS as described above, and the remaining groups can be arbitrarily assigned to pairings. It immediately follows from above that it is optimal for each individual in each group to contribute 100%.

A.2 The ICS extended to pairings of groups with different sizes

Let group A have *N* members and group B have *M* members and $N \neq M$. For simplicity, assume $w_i = w_j \forall w$. A modified ICS can be implemented where the aggregate contributions of the second group B are transformed into a value that is comparable to the aggregate contributions of group A. This is done by converting the aggregate contributions of group B into a proportion of its group's aggregate wealth then expressing this in terms of the aggregate wealth of group A.

$$\pi_i^A = (w - t_i^A) + \frac{a}{N}\sum_{j=1}^{N} t_j^A + \delta\left(\sum_{j=1}^{N} t_j^A - \frac{\sum_{j=1}^{M} t_j^B \cdot \sum w^A}{\sum w^{\mathbf{B}}}\right)$$

The payoff function for an individual in group B becomes:

$$\pi_i^B = (w - t_i^B) + \frac{a}{N}\sum_{j=1}^{N} t_j^B + \delta\left(\frac{\sum_{j=1}^{N} t_j^B \cdot \sum w^A}{\sum w^B} - \sum_{j=1}^{M} t_j^A\right)$$

Because only one group's aggregate contributions are transformed (in terms of the other) the inter-group MPCR (δ) is invariant to the transformation.

Further, this transformation still satisfies the condition for a balanced budget:

$$\delta\left(\sum_{j=1}^{N} t_j^A - \frac{\sum_{j=1}^{M} t_j^B \cdot \sum w^A}{\sum w^{\mathbf{B}}}\right) + \delta\left(\frac{\sum_{j=1}^{N} t_j^B \cdot \sum_{j=1}^{M} t_j^A}{\sum w^B} - \sum_{j=1}^{M} t_j^A\right) = 0$$

A.3 The ICS can apply to groups of any size

Both intra-group and inter-group MPCRs are invariant to increases in *N*. However, the maximum size of the inter-group transfer $\delta(\sum_{j=1}^{N} t_j^B - \sum_{j=1}^{N} t_j^A)$ increases with *N*. Large group sizes can increase the opportunity for bankruptcy in out of equilibrium play[24]. The ICS works best in small groups.

[24] This is not the case with the size of the intra-group return $\frac{a}{N}\sum_{j=1}^{N} t_j^A$ which remains constant with increases of *N* due to its denominator.