Modes of Collective Action in Village Economies: Evidence from Natural and Artefactual Field Experiments in a Developing Country

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In a canonical model of collective action, individual contribution to collective action is negatively correlated with group size. Yet, empirical evidence on the group size effect has been mixed, partly due to heterogeneities in group activities. In this paper, we first construct a simple model of collective action with the free rider problem, altruism, public goods, and positive externalities of social networks. We then empirically test the theoretical implications of the group size effect on individual contribution to four different types of collective action, i.e., monetary or nonmonetary contribution to directly or indirectly productive activities. To achieve this, we collect and employ artefactual field experimental data such as public goods and dictator games conducted in southern Sri Lanka under a natural experimental situation where the majority of farmers were relocated to randomly selected communities based on the government lottery. This unique situation enables us to identify the causal effects of community size on collective action. We find that the levels of collective action can be explained by the social preferences of farmers. We also show evidence of free riding by self-interested households with no landholdings. The pattern of collective action, however, differs significantly by mode of activity—collective action that is directly rather than indirectly related to production is less likely to suffer from the free rider problem. Also, monetary contribution is less likely to cause free riding than nonmonetary labor contribution. Unlike labor contributions, monetary contributions involve collection of fees which can be easily tracked and verified, possibly leading to better enforcement of collective action.

Keywords: collective action, social preference, natural and artefactual field experiment, irrigation, South Asia

JEL codes: C93, H41, H54, O13, Q15

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I. Introduction

In the real world, most political, social, or economic activities are undertaken by groups. Naturally, there has been active academic research in identifying determinants of individual contributions to collective action within a group. Particularly, group size and social and economic heterogeneities among group members are regarded as important determinants of members’ effort levels.\(^1\) While the canonical theory of free riding implies a negative relationship between group size and individual contribution (Olson 1965, Holmstrom 1982), empirical studies on the group size effect present mixed results (Bandiera et al. 2005, Banerjee et al. 2007).\(^2\) Ostrom (2011, p. 52) stated that, “Unfortunately, we do not find that single variables such as size of group or amount of payoffs are always associated with failure or success in achieving collective action.” This paper aims to shed new light on heterogeneous group size effects of collective action by employing artefactual field experimental data collected under a unique natural experimental situation in Southern Sri Lanka.

In the existing studies, mixed empirical evidence on the group size effect may arise from the following reasons. First, the net effect of group size on collective action is not necessarily theoretically unambiguous (Banerjee et al. 2007, Esteban and Ray 2001). It depends on the nature of goods, i.e., whether they are local private goods or public goods (Agrawal and Goyal 2001, Banerjee et al. 2007, Dayton-Johnson 2000). As Esteban and Ray (2001) argue, when the collective good produced is purely private, an inverse relationship between effective collective action and group size arises but when the collective good is purely public and fully non-excludable, the free rider problem never emerges.

Collective action also reflects team production technologies—concavity or convexity, monitoring and commitment devices, and monetary incentives. If there is a convex technology arising from positive network effects, it is even possible to observe a positive correlation between individual contribution to collective action and group size. Also, a particular incentive contract can generate a positive group size effect too (Bandiera et al. 2005).

The conventional theories consider one-shot non-cooperative games by selfish individuals. In this framework, collective action is poorly induced because of the prisoner’s dilemma (Rapoport and Chammah 1965), which alternatively can be called the problem of free riding (Olson 1965) or the tragedy of the commons (Hardin 1968). On the other hand, the repeated-game framework predicts cooperation without commitment or third-party enforcement. This may be due to social capital among

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\(^1\) Bandiera et al. (2005), Banerjee et al. (2007), and Fayssse (2005), discuss broader issues on collective action. 
\(^2\) Bardhan (2000) and Fujiie et al. (2005) find a negative community size effect, where increasing the community size reduces individual contribution to irrigation maintenance. On the other hand, Dayton-Johnson (2000) and Khwaja (2009) find insignificant community size effects. Agrawal and Goyal (2001) theoretically and empirically show that a medium-sized group is more suitable to manage collective action. In experimental studies employing the public goods game, Isaac and Walker (1988) show that an individual’s contribution declines in larger groups, a result attributed to the decline in marginal benefit.
group members which solve the moral hazard and enforcement problems (Anderson et al. 2004, Durlauf and Fafchamps 2005). Moreover, individual contribution to collective action can be explained by pro-social behavior such as altruism and voluntary cooperation (Chen and Li 2009, Falk and Fischbacher 2006, Fehr and Fischbacher 2002).

Previous studies examined the group size effect without focusing on heterogeneities in characteristics of group activities. Individuals, however, may act differently when collective activities are for production purposes rather than when they are for nonproduction purposes such as ceremonial and funeral events. Whether the nature of contribution is monetary or non-monetary may also change individual’s incentives significantly.

Finally, existing empirical studies do not take into account the endogeneity of group sizes, potentially leading to estimation bias (Bandiera et al. 2005, p. 475; Kosfeld et al. 2009). Hence, the lack of a clear relationship between group size and collective action may be the result of econometric problems. For example, a community may have a specific mechanism to control group size so that it can maintain a desirable level of collective action. This will generate reverse causality.

This paper aims to carefully address these issues. First, we investigate how the individual contribution varies across preferences, production technologies, and types of collective action. Second, we exploit a natural experimental situation to address the concern regarding endogenous community size. To achieve these goals, we first illustrate the mixed group size effects in the augmented Holmstrom (1982) model by differentiating local private goods from public goods, incorporating altruism, and considering scale economies. Then, we empirically identify the causal relationship between group size and collective action using unique data from a large-scale irrigation system in Southern Sri Lanka called the Walawe Left Bank (WLB) Irrigation Area where an irrigation upgrading and extension project was implemented from 1995 until 2008 with financial assistance from a Japanese ODA loan. This project provides us with natural experiments where the group sizes were assigned exogenously since lands were allocated by quasi-lottery mechanisms. Artefactual field experiments are used in order to elicit altruism and willingness to cooperate. Finally, by combining these data, we compare four types of collective action—monetary or nonmonetary contribution to productive or nonproductive (indirectly productive) activities—to uncover differences in the patterns of voluntary contribution.

To preview the results of our empirical analysis, the pattern of collective action differs significantly by mode of activity. First, irrigation maintenance activities

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3 Experimental studies show that participants of public goods games contribute some amount between the self-interested equilibrium and the social optimum (Ledyard 1995).

4 Shoji et al. (2010) use the same dataset as this paper and examine the way in which the heterogeneity of crop choice affects participation in community work, but they do not compare various modes of collective actions.

5 An artefactual field experiment is defined as a conventional laboratory experiment conducted with non-standard subjects (Harrison and List 2004, p. 1014).
that are directly related to production are less likely to suffer from the free rider problem. In contrast, free riding is widespread in indirectly productive activities such as expenses for ceremonies and participation in community work. We also find that monetary contribution is less likely to cause the free rider problem than nonmonetary contribution for both irrigation maintenance and community events. Finally, selfish farmers with no landholdings are less likely to contribute in larger communities.

The rest of this paper is organized as follows. Section II describes the theoretical framework. The study site, our dataset, and the empirical strategies are discussed in Section III. Section IV presents the expected results followed by concluding remarks in Section V.

II. The Theoretical Model

We augment the basic Holmstrom (1982) model of team production to determine the amount of effort provided by farmers. We do so by incorporating altruism and the scale effect of social networks. Suppose that there are \( N \) farmers, who jointly produce a single output, \( g \), that is, for example, the quality of an irrigation facility or system. The amount of effort from the \( i \)th farmer is denoted by \( a_i \). Therefore, the joint output, e.g., the level of irrigation quality, can be described by the following function:

\[
g = g(a_1, a_2, a_3, \ldots, a_N; X_1, X_2, X_3, \ldots, X_N), \]

where \( X_i \) is a matrix of observables which affect the output. Let us assume that the utility function of a farmer \( i \) is expressed as \( u_i = s_i - a_i \), where \( s_i \) is the output share of farmer \( i \).

The efficient regime of this economy can be solved as the following social planner problem:

\[
\text{Max} \{ a_i \} \quad \text{subject to} \quad g(a_1, a_2, \ldots, a_N; X) - \sum_{i=1}^{N} a_i = 0.
\]

The first-order condition (FOC) of this problem is

\[
\frac{\partial g}{\partial a_i} = 1.
\]

Suppose that the function \( g \) takes an additive separable form:

\[
g(a_1, a_2, \ldots, a_N; X) = \sum_{i=1}^{N} X_i a_i^{\gamma_i},
\]

where \( \gamma_i < 1 \). Then the FOC becomes,

\[
X_i \gamma_i a_i^{\gamma_i - 1} = 1,
\]

and the Pareto optimal level of effort, \( a_i^* \) which satisfies this FOC becomes:

\[
a_i^* = \left( X_i \gamma_i \right)^{\frac{1}{1-\gamma_i}}.
\]

In contrast, a Nash equilibrium is derived by solving an individual farmer’s utility maximization problem:

\[
\text{Max}_{a_i} s_i(g) - a_i,
\]

given the production technology, \( g \), where \( s_i(g) \) is the sharing rule or technology of the joint output. The FOC is:

\[
\frac{\partial s_i}{\partial g} \frac{\partial g}{\partial a_i} + \frac{\partial s_i}{\partial a_i} = 1,
\]

where \( \frac{\partial s_i}{\partial g} \) denotes private benefit from the irrigation infrastructure and \( \frac{\partial g}{\partial a_i} \) denote the marginal output of effort. This FOC gives an individually optimal effort level, \( a_i \). Under the functional form of production technology, we have the

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6Alternatively, we can employ a general convex disutility function from effort provision, denoted by \( v_i(a_i) \). Such a generalization will not change the qualitative results.
individual optimal effort level: $\lambda_i X_i \gamma_i a_i^{\gamma_i - 1} = 1$, where $\lambda_i \equiv \partial s_i / \partial g$. In equation (2), $\lambda_i$ is a weight which shows the degree of benefit a farmer $i$ obtains from this joint irrigation management. This FOC provides us with the effort level under individual optimization of:

$$a_i = (\lambda_i X_i \gamma_i)^{\frac{1}{\gamma_i}}. \quad (2)$$

We consider three cases of team production: the first case when the collective good is purely private, the second when there is positive altruism and/or voluntary public goods contribution, and the third when the collective good is a public good or involves positive externalities from a social network.

A. Joint Production of Pure Local Private Goods

The case of pure local private goods, which are rivalrous, can be formalized by a condition, $\sum_{i=1}^{N} s_i = g$, or equivalently, $\sum_{i=1}^{N} \lambda_i = 1$. For expositional purpose, if we further assume that the benefit of irrigation is equally divided among participants, then we have $s_i = g/N$ and thus the optimal effort level becomes: $a_i^P = (X_i \gamma_i / N)^{\frac{1}{\gamma_i}}$, which is strictly smaller than $a_i^*$ if $N > 1$. This is the moral hazard problem in team production formalized by Holmstrom (1982). It is evident that the requirements of the Pareto optimal effort level and the individual optimal level contradict each other if $N > 1$. The only situation where the Nash equilibrium is at a Pareto optimum is when there is only one farmer, i.e., $N = 1$, $\lambda_i = 1$, and thus $a_i^P = a_i^*$. However, as $N$ increases, the gap between the Pareto optimal effort level and the individually optimal effort level widens because of the free rider problem (Rahman and Sawada 2012).

B. Joint Production of Pure Local Private Goods with Altruism

To investigate the case of pure private goods with altruism, we assume that the utility function of a farmer $i$ takes an additive separable form, $u_i = s_i + \rho(\sum_{j \neq i} s_j) - a_i$, where $\rho$ is the altruism parameter. Since equally divided private goods can be described by $s_i = g/N$ for all $i$, we now have: $u_i = g[1 + \rho(N - 1)] / Na_i$. Hence, $\lambda_i^A = \partial s_i / \partial g = [1 + \rho(N - 1)] / N > 1/N$ if $N > 1$ and $\rho > 0$. This means that the optimal effort level under private goods with altruism becomes:

$$a_i^A = (\lambda_i^A X_i \gamma_i)^{\frac{1}{\gamma_i}}, \quad (3)$$

which is larger than $a_i^P$ under the assumptions of $N > 1$ and $\rho > 0$. Also, it is easy to show that $\partial a_i^A / \partial \rho > 0$. These analytical results indicate that altruism mitigates the free rider problem unambiguously. Note that in the case of full altruism with $\rho = 1$, $a_i^A = a_i^*$, indicating that the individual solution becomes socially optimal. In other
words, the free rider problem arises when there are multiple farmers who are motivated by self-interest over private goods.

C. The Case of Pure Public Goods

The case of pure public goods with non-excludability and non-rivalry, can be described by the case of \( s_i = g \) for all \( i \), or, alternatively, \( \lambda_i \equiv \partial s_i / \partial g = 1 \) for all \( i \). It is straightforward to show that individual optimization can achieve social optimality. In addition to the condition that \( \lambda_i \geq 1 \), positive “perceived” externalities arising from the group social network can be formulated by the case of \( \partial \lambda_i / \partial N > 0 \). In this case, the individual effort level will be even higher than that of the social optimal.

III. Study Site and Data Description

A. Study Site

Our study site is the Walawe Left Bank (WLB) Irrigation Area, located in the Hambantota and Moneragal districts in the southern part of Sri Lanka. Figure 1 shows the map of five study blocks in this region. In this area, the WLB Irrigation Upgrading and Extension Project was implemented from 1995 until 2008 with

![Figure 1. Study Site](http://direct.mit.edu/adev/article-pdf/30/1/31/1640785/adev_a_00002.pdf)

Source: Authors’ compilation.
Table 1. Categories of Collective Action

| Monetary contribution | Direct Production Activity | Indirect Production Activity |
|------------------------|----------------------------|------------------------------|
|                        | Expenses for irrigation maintenance | Expenses for ceremonial events |
| Nonmonetary contribution| Labor participation in irrigation maintenance | Labor participation in community work |

financial assistance from a Japanese ODA loan (JBIC Institute 2007). Under this project, the old irrigation system was rehabilitated and a new irrigation system was constructed. In this project area, all farmers received fairly homogenous land: 0.2 hectares (ha) of land for residence and 1.0 ha of irrigated paddy field or 0.8 ha of field for other food crops.

Rehabilitation and construction started in the north of WLB close to the Uda Walawe reservoir and gradually extended toward the south. By the end of the first phase of the project, 2,900 ha of the irrigated area were rehabilitated and 1,040 ha of irrigated area were newly developed in the northern blocks such as the Sevanagala, Kiribbanwewa, and Sooriyawewa blocks (Figure 1). In the second phase, an additional 5,340 ha of irrigation system was newly constructed in the southern part of WLB, the extension area. By the end of 2008, almost all households had access to irrigation facilities except for the rain-fed part of Sevanagala block, i.e., Block 2 in Figure 1.

The structure of the WLB canal system is composed of the main canal, the branch canals, the distribution canals, and the field canals with the last one being the smallest unit. In each distribution canal (D-canal), there is a formal organization called the Farmers’ Organization (FO), which is used as a unit of collective action in this paper. According to the farmers’ responses to our survey, the objectives of FOs are to maintain irrigation facilities and communal roads, procure farm inputs collectively, cooperatively market products, and prepare for community activities such as religious festivals, funerals, and weddings. All farmers in the irrigated areas are required to register with the FO. While registered farmers are supposed to contribute to activities of the registered FO, an effective enforcement mechanism of such contribution is not necessary in place. In this study, we consider the FO as a unit of the community to perform collective action and, in the areas without access to irrigation facilities, we use villages as a unit of community.

We focus on four different types of collective action organized by FOs: (i) expenses for irrigation maintenance, (ii) labor participation in irrigation maintenance, (iii) expenses for ceremonies, and (iv) participation in community work. As summarized in Table 1, we classify these actions, respectively, as: (i) monetary contributions to productive activity, (ii) nonmonetary contributions to productive activity, (iii) expenses for ceremonial events, and (iv) labor participation in community work.
Table 2. Implementation of Land Allocation

| Any opportunity to state your preferences? | Residences (Obs. = 165) | Irrigated Plots (Obs. = 150) |
|-------------------------------------------|-------------------------|------------------------------|
| Not at all                                 | 29.70%                  | 31.54%                       |
| Block level                               | 10.91%                  | 12.75%                       |
| Unit-canal level                           | 2.42%                   | 2.69%                        |
| D-canal level                              | 1.21%                   | 2.01%                        |
| Plot level                                 | 55.76%                  | 51.01%                       |
| Total                                     | 100.00%                 | 100.00%                      |

| Land allocation process                    | Obs. = 162              | Obs. = 148                   |
|-------------------------------------------|-------------------------|------------------------------|
| Acquired the preferred area without process| 51.23%                  | 45.95%                       |
| Lottery within or outside the claimed area | 24.08%                  | 29.06%                       |
| First come, first served basis            | 8.02%                   | 9.46%                        |
| Negotiation among the resettlers          | 3.70%                   | 4.05%                        |
| No formal permission regarding land use   | 8.64%                   | 6.76%                        |
| Others                                    | 4.32%                   | 4.73%                        |
| Total                                     | 100.00%                 | 100.00%                      |

Source: Panel dataset collected by authors from seven surveys conducted during 2001–2009.

activity, (iii) monetary contributions to indirectly productive activity, and (iv) non-monetary contributions to indirectly productive activity. Irrigation maintenance is one of the most important tasks of FOs (Shoji et al. 2012). Expenses for ceremonies include those for religious festivals, funerals, and weddings.\(^8\) Regarding community work, FO members attend informal meetings, or *Shramadana*, literally meaning free labor supply, and devote their time to community activities such as cleaning communal roads and preparing for religious festivals.

**B. Natural Experiment**

An important unique feature of this irrigation area is that the size of FO was exogenously determined for each household due to a particular land distribution process, which enables us to identify the causal relationship between group size and collective action. Interestingly, when the government distributed irrigated plots and residences to farmers, the government used lotteries in each block. Table 2 reports that approximately 30% of households followed this process and received plots for certain crops regardless of their characteristics. As to the remaining farmers, around 50% of households could claim their preference on the location of plots at the plot level. Such households were basically those who had lived in the project areas before project implementation and therefore were forced to relocate. However, it may still

\(^8\)It should be noted that there is the possibility that households could have spent for ceremonies in different FO communities. However, the ceremony groups, such as funeral societies, are formed based on geographical characteristics and this largely overlaps with FO communities. Therefore, we still use the FOs as a unit of this collective action.
be reasonable to assume that the “size” of FO is exogenous given for farmers even without the lottery process because the exact routes of the irrigation canals and thus number of farmers connected to their own distribution canals were not known prior to construction. Indeed, the observed household characteristics, such as household head characteristics and demographics, are not significantly different between the farmers with and without the lottery process (Shoji et al. 2010). Hence, we consider community and household characteristics—e.g., the size of FOs, neighborhood characteristics, irrigation access, and distance to their plots—to be exogenous.9 Yet, we also perform robustness checks by including household fixed effects and period-specific block effects.

C. Data and Experimental Design

This study uses a seven-round panel dataset which we collected from 2001 until 2009. The first four surveys were conducted in June and October of 2001 and June and October of 2002 with 858 randomly selected households, which comprise about 4.6% of the total population of 18,767 households (Hussain et al. 2002). The timing of each survey corresponds to the cropping season in the study area. In June and October 2007, in order to examine the five-year changes in livelihoods in the formerly and newly irrigated areas, the fifth and sixth surveys were conducted with 193 households who were randomly chosen out of the original 858 households. Finally, in March 2009, we conducted the artefactual field experiments such as public goods and dictator games with a total of 268 households: 186 from the original 858 households and 82 newly invited households.10

The dictator game is played by two participants, a sender called a dictator and a receiver (Camerer and Fehr 2004, Levitt and List 2007, Cardenas and Carpenter 2008). The two are randomly matched from the same distribution canal in an anonymous setting. The sender receives 500 Sri Lanka rupees (SLRs) of the initial endowment—roughly equivalent to the prevailing daily wage in the area—from experimenters and the receiver gets nothing initially. The dictator can then transfer as much as he wishes of his endowment to the receiver from the possible transfer amounts. The material payoff of the dictator and receiver are \(500 - \rho\) and \(\rho\), respectively, where \(\rho\) denotes the amount he allocates to the receiver and \(\rho \in \{0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500\}\). Since there is no reason for self-interested dictators to transfer money and the dictator’s zero transfers is a Nash equilibrium, the amount of transfer is interpreted as a measure of pure altruism (Camerer and

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9For the details of the test on the exogeneity of land allocation to the settlers, see Aoyagi et al. (2013). They regress settlers’ observed characteristics in comparing across blocks, where the government has done the relocation programs gradually from north blocks to south blocks. The results show that households were exogenously allocated to D-canal as well as within D-canal area.

10 While the sample size changes across the surveys, according to our qualitative assessment of the survey results, this is not because of migration or refusal of the survey households.
Fehr 2004). Since we asked all participants from each distribution canal to play as both dictator and receiver using the strategy method in an anonymous setting, we were able to obtain the altruism measure of all participants.

The second artefactual experiment is the canonical public goods game (Camerer and Fehr 2004, Levitt and List 2007, Cardenas and Carpenter 2008). In this game, each participant is placed in a group of four participants from the same distribution canal anonymously with the initial endowment of SLRs500. Each group has an investment project in public goods. The total investment amount by the group members is doubled by the experimenters and returns back to the four participants equally regardless of the individual contribution amounts. The material payoff of participants is the sum of the amount kept initially and the reallocation from the public goods. Each participant decides how much out of the endowment to contribute to the public goods under this situation. Again, the zero investment amount is the Nash equilibrium, and thus the positive investment amount can be interpreted as a measure of reciprocally expected cooperation (Camerer and Fehr 2004), altruism, fairness, and conditional reciprocity (Levitt and List 2007), or social capital (Anderson, Mellor, and Milyo 2004).

The empirical analysis of this study uses the 186 households which participated in both the panel surveys and the experiment, making the panel sample size of our econometric analysis 1,072 samples. Figure 2 presents the results of the public goods game and dictator game experiments (Cardenas and Carpenter 2008). We can see that a majority of subjects exhibit pro-social behavior by sending positive amounts in these two games.

Figure 3 depicts the kernel density of FO size, showing two peaks around at 120 households and 250 households. Table 3 shows the descriptive statistics of the variables used in this paper by the size of FO community (note that we set the median

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11The instructions of these experiments are available from the corresponding author upon request.
12Since the FO size variable includes missing values, we use the mean value of reported data at the D-canal level.
Panel A reports descriptive statistics of the four collective action variables that we use as dependent variables. It is shown that large communities are less likely to participate in production activities, although we can verify that the opposite tendency applies to the other activities. Panel B of Table 3 summarizes the descriptive statistics of the independent variables. Since these variables do not change much over time, Panel B reports the numbers from the first-round survey only. We confirm that most household characteristics are uncorrelated with the FO size. While the land sizes and numbers of children are systematically different depending on the size of FO, we will use these variables as control variables in regression.

D. Empirical Strategy

We empirically implement the theoretical implication contained in equation (3) because the marginal share variable, $\lambda$, summarizes the different cases we present in the theory section. More importantly, our econometric strategy utilizes the natural experimental situation to examine the impact of exogenous community size, $N$, on the contribution to the four types of collective actions. Specifically, we
Table 3. Descriptive Statistics of Variables

| Panel A: Collective Action Variables (binary variables) | FO Less Than 126 Households | FO More Than 126 Households | Mean | S.D. | Mean | S.D. | Diff. |
|--------------------------------------------------------|-----------------------------|-----------------------------|------|------|------|------|-------|
| Expenses for Irrigation Maintenance                    | 0.288                       | 0.212                       | 0.409|      |      |      | 0.453 |
| Participation in Irrigation Maintenance                | 0.201                       | 0.164                       | 0.371|      |      |      | 0.401 |
| Expenses for Ceremonies (religious festivals, funerals, weddings) | 0.562                       | 0.625                       | 0.485|      |      |      | 0.497 |
| Participation in Community Works (Shramadana)          | 0.740                       | 0.778                       | 0.416|      |      |      | 0.439 |
| Observations                                           | 573                         | 499                         |      |      |      |      |      |

Panel B: Control Variables

Time-Variant Variables

| Size of Farmers’ Organization (× 10³ households)         | 0.083                       | 0.175                       | 0.049|      |      |      | 0.030 |
| Holdings of unirrigated land (ha)                       | 1.299                       | 2.022                       | 1.781|      |      |      | 1.516 |
| Holdings of irrigated land (ha)                         | 1.435                       | 1.032                       | 1.169|      |      |      | 1.201 |
| Observations                                           | 573                         | 499                         |      |      |      |      |      |

Time-Invariant Variables

| Investing proportion in the public goods game            | 0.436                       | 0.414                       | 0.243|      |      |      | 0.237 |
| Sending proportion in the dictator game                  | 0.295                       | 0.267                       | 0.207|      |      |      | 0.212 |
| Age of head (× 10³)                                      | 0.047                       | 0.044                       | 0.010|      |      |      | 0.011 |
| Schooling years of head                                  | 5.773                       | 5.347                       | 3.230|      |      |      | 3.272 |
| Female-headed dummy                                      | 0.102                       | 0.061                       | 0.241|      |      |      | 0.305 |
| Males aged 16 or over                                    | 1.761                       | 1.561                       | 0.850|      |      |      | 1.093 |
| Females aged 16 or over                                  | 1.784                       | 1.643                       | 0.997|      |      |      | 0.976 |
| Children                                                | 1.386                       | 2.143                       | 1.478|      |      |      | 1.245 |
| Distance to city (km)                                    | 4.460                       | 4.398                       | 1.984|      |      |      | 4.030 |
| Sample households                                        | 88                          | 98                          |      |      |      |      |      |

Note: Significant at *** 1% and ** 5% level. The data were collected in 2009, at the seventh round of surveys. However, for time-invariant statistics, Panel B reports the numbers from the first round.

Variables take the value of one if the household contributes to the activities at least once during the survey period, zero otherwise.

Source: Panel dataset collected by authors from seven surveys conducted during 2001–2009.

estimate the following estimation equation which is based on equation (2) and (3):

\[ \alpha_{itj} = \lambda_j (\rho_i, N_{it}) + X_{itj} \beta_j + u_{jt} + u_{B,t} + \epsilon_{itj}, \]  

where \( \alpha_{itj} \) is a proxy for the effort level, \( \alpha_i \), and takes the value of one if household \( i \) contributes to activity \( j \) at period \( t \) and zero otherwise. The number of households in the FO community is denoted by \( N \). \( X \) includes the other observable determinants of collective action such as irrigated and un-irrigated landholdings, indicators of household preference, household head characteristics, demographics, and geographic characteristics. Regarding the household preference, \( \rho \), we use the results of the dictator and the public goods games, as measures of altruism and voluntary cooperativeness, respectively. The last three terms in the right-hand side of
equation (3) are the household fixed effects, period-specific block effects, and a well-behaved error term, respectively.

To distinguish the different cases of collective action described in the theory section, we estimate equation (4) by assuming the function, $\lambda(\cdot)$ is a piece-wise linear function of the community size and the interaction terms with the preference variables and landholdings. i.e.,

$$
\lambda^j(\rho_{it}, N_{it}) = \delta^j_1 N_{it} + \delta^j_2 N_{it} \cdot \rho^j_1 + \delta^j_3 N_{it} \cdot \rho^j_2 + \delta^j_4 N_{it} \cdot L^U_{it} + \delta^j_5 N_{it} \cdot L^I_{it}
$$

(5)

where $\rho^j_1$ denotes the proportion of investment out of the endowment in the public goods game. Similarly, $\rho^j_2$ denotes the proportion of endowment that the respondent transferred to his partner in the dictator game. The remaining two variables, $L^U_{it}$ and $L^I_{it}$ are un-irrigated and irrigated land sizes, respectively.

Under our natural experimental situation, we believe that we can plausibly assume that $N$ in equation (5) and $\varepsilon$ in equation (4) are uncorrelated, generating unbiased estimates of $\delta_1$, $\delta_2$, $\delta_3$, $\delta_4$, and $\delta_5$. To mitigate remaining confounding factors, we employ the linear probability model with household level and/or period-specific block level fixed effects. In all estimations, we use the cluster-adjusted robust standard errors at the D-canal level. This addresses the possible correlation of residuals over time across households within each D-canal community.

IV. Empirical Results

A. Regression Results

Table 4 reports the estimation result of the four dependent variables separately shown in specification blocks A, B, C, and D. The first column of each variable block shows the simplest specifications without the cross terms of farmer organization size and household fixed effects. In these specifications, community size does not systematically predict contribution to collective action. While these unclear empirical results may be seen as consistent with the existing studies, the lack of robustness may be generated by specification errors. As to the other variables, the first column of block A shows that irrigated and un-irrigated land ownership, respectively, are correlated with higher and lower contribution to irrigation maintenance expenses. The other three blocks also show a similar qualitative result although coefficients are statistically insignificant.

Columns 2 and 3 in each block include the cross terms, and are estimated without and with the household fixed effects, respectively. The third column of the four blocks indicates evidence that a large community involves a small contribution amount to collective action: First, the coefficients $\delta_1$ are negative and statistically significant in column 3 of blocks A and D, suggesting that selfish households
Table 4. Regression Results—Linear Probability Model

|                  | A. Productive, Monetary Expenses for Irrigation Maintenance | B. Productive, Nonmonetary Participation in Irrigation Maintenance | C. Indirectly Productive, Monetary Expenses for Ceremonies | D. Indirectly Productive, Nonmonetary Participation in Community Works |
|------------------|------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------|
| Period specific  | Yes                                                        | Yes                                                             | Yes                                                      | Yes                                                          |
|                   | block fixed effects                                        |                                                                  |                                                          |                                                              |
| Household fixed   | No                                                         | No                                                              | No                                                       | No                                                          |
|                   | effects                                                    |                                                                  |                                                          |                                                              |
| Nonlinear impact  | No                                                         | Yes                                                             | Yes                                                      | No                                                          |
| of FO size?       | (1)                                                       | (2)                                                             | (3)                                                     | (1)                                                        |
| \( \delta_1 \):  | 0.2213                                                    | -0.1889                                                         | -0.6326*                                                 | -0.2453                                                     |
| Size of Farmers’  | (0.166)                                                   | (0.603)                                                         | (0.357)                                                 | (0.305)                                                     |
| Organization      |                                                            |                                                                  |                                                          |                                                              |
| Investing proportion in the public goods game | -0.0716                                                   | 0.0395                                                          | 0.0142                                                   | 0.0444                                                      |
| \( \delta_2 \):  | -0.0716                                                   | 0.0395                                                          | 0.0142                                                   | 0.0444                                                      |
| x Size of FO      | (0.052)                                                   | (0.073)                                                         | (0.040)                                                 | (0.071)                                                     |
| Sending proportion in the dictator game | 0.0528                                                   | 0.0419                                                          | 0.0111                                                   | -0.0007                                                     |
| \( \delta_3 \):  | 0.0528                                                   | 0.0419                                                          | 0.0111                                                   | -0.0007                                                     |
| x Size of FO      | (0.063)                                                   | (0.145)                                                         | (0.073)                                                 | (0.122)                                                     |
| Holdings of un-irrigated land | -0.0154*                                              | -0.0373                                                         | 0.0023                                                   | -0.0173                                                     |
| \( \delta_4 \):  | -0.0154*                                                  | -0.0373                                                         | 0.0023                                                   | -0.0173                                                     |
| x Size of FO      | (0.008)                                                   | (0.022)                                                         | (0.006)                                                 | (0.011)                                                     |
| Holdings of irrigated land | 0.0514*                                                | -0.0079                                                         | 0.0186                                                   | 0.0139                                                      |
| \( \delta_4 \):  | 0.0514*                                                   | -0.0079                                                         | 0.0186                                                   | 0.0139                                                      |
| x Size of FO      | (0.026)                                                   | (0.047)                                                         | (0.016)                                                 | (0.013)                                                     |

Continued.
Table 4. Continued.

|                          | A. Productive, Monetary Expenses for Irrigation Maintenance | B. Productive, Nonmonetary Participation in Irrigation Maintenance | C. Indirectly Productive, Monetary Expenses for Ceremonies | D. Indirectly Productive, Nonmonetary Participation in Community Works |
|--------------------------|------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------------|
| **δ₅: x Size of FO**     | 0.5015*                                                   | 0.6750**                                                   | -0.5026*                                          | -0.3281                                                   |
|                          | (0.257)                                                   | (0.262)                                                   | (0.249)                                            | (0.236)                                                   |
| **Age of head**          | 3.7056**                                                 | 3.5404**                                                 | 3.3118                                            | 4.7176                                                   |
|                          | (1.477)                                                   | (1.629)                                                   | (3.578)                                            | (4.020)                                                   |
| **Schooling years of head** | 0.0008                                                   | 0.0002                                                   | 0.0140                                            | -0.0016                                                  |
|                          | (0.004)                                                   | (0.008)                                                   | (0.005)                                            | (0.005)                                                   |
| **Female-headed dummy**  | -0.0119                                                   | -0.0138                                                   | -0.0532                                           | -0.0937*                                                  |
|                          | (0.045)                                                   | (0.112)                                                   | (0.052)                                            | (0.051)                                                   |
| **Males aged 16 or over**| -0.0054                                                   | -0.0046                                                   | -0.0084                                           | -0.0016                                                  |
|                          | (0.025)                                                   | (0.030)                                                   | (0.012)                                            | (0.012)                                                   |
| **Females aged 16 or over** | -0.0017                                                   | -0.0022                                                   | -0.0084                                           | -0.0026*                                                  |
|                          | (0.014)                                                   | (0.030)                                                   | (0.015)                                            | (0.014)                                                   |
| **Children**             | 0.0024                                                   | 0.0022                                                   | -0.0084                                           | -0.0087                                                  |
|                          | (0.008)                                                   | (0.026)                                                   | (0.007)                                            | (0.006)                                                   |
| **Distance to city**     | -0.0111                                                   | -0.0128                                                   | 0.0035                                            | -0.0057                                                  |
|                          | (0.008)                                                   | (0.004)                                                   | (0.004)                                            | (0.004)                                                   |
| **Constant**             | 0.5087***                                                 | 0.5772***                                                 | 0.2697                                            | 0.5081**                                                  |
|                          | (0.094)                                                   | (0.162)                                                   | (0.163)                                            | (0.210)                                                   |

H₀: δ₄ = δ₅
H₀: δ₁ = δ₂ = δ₃ = δ₅ = 0

| Observations | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 | 1,067 |
|--------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| R-squared    | 0.570 | 0.573 | 0.564 | 0.243 | 0.248 | 0.227 | 0.064 | 0.065 | 0.068 | 0.149 | 0.153 | 0.168 |

Significant at **1%**, *5%, and *10% level.
Note: Cluster-adjusted robust standard errors are in parentheses. Five observations are dropped because of data problems.
with no landholdings are less likely to contribute to the collective action in larger communities. This result is consistent with the theoretical implication of the free rider problem in the case of pure private goods.

Second, the coefficients for the interaction variable of public goods contribution and group size, $\delta_2$, are negative except for block C. This suggests that the marginal effect of cooperativeness declines as community size becomes larger, which is consistent with the canonical free rider model with pure private goods.

Yet, the table also shows results that are not simply explained by the team production framework or pro-social behaviors: directions and statistical significance of the altruism coefficient, $\delta_3$, are not necessarily consistent across specifications and activities. The coefficients of un-irrigated landholdings are largely negative, and the cross terms with the size of farmer organization, $\delta_4$, are positive in most cases (column 3 of blocks A, B, and D). These results suggest that when the group size is small, the marginal effect of the un-irrigated land size is negative but turns to be positive as the size becomes larger. A similar positive size effect can be found for irrigated land size when considering monetary contribution to productive activities, i.e., the coefficient $\delta_5$ in column 3 of block A. A possible interpretation is the case of public goods with positive externalities arising from social networks (Labonne and Chase 2011). The return to the social network investment would be larger when the group size is larger, and our result is consistent with this interpretation.

Finally, in order to check robustness of these findings, we also include a private water accessibility variable which is represented by the number of owned water pumps as an additional explanatory variable, although only less than 10% of our sample households own such pumps. The estimation results are the same qualitatively.\(^{13}\)

### B. Marginal Effect of Community Size

To capture the marginal effect of community size on collective action variables, we compute the following predicted value of the marginal group size effect based on the third column for each dependent variable in Table 4:

$$\frac{\partial \hat{\alpha}_{it}}{\partial N_{it}} = \hat{\delta}_1 + \hat{\delta}_2 \cdot \rho_1 + \hat{\delta}_3 \cdot \rho_2 + \hat{\delta}_4 \cdot L_{it}^U + \hat{\delta}_5 \cdot L_{it}^I$$

\(^{13}\)One might still be concerned about the potential bias by the heterogeneity in the quality of farmer organizations such as the governance structure and the age of organizations. However, the governance structure is expected to be homogeneous since they were all newly established under the irrigation project. While the age of organizations varies across the areas, heterogeneities arising from the organization age variation should be captured by the block fixed effects.
Based on equation (6), we then draw the cumulative distribution function (CDF) of these predicted values of the marginal group size effect (Figure 4). Two patterns can be seen from the figure.

First, irrigation maintenance activities directly related to production are less likely to suffer from the free rider problem. Intriguingly, the marginal group size effect of equation (4) is estimated to be positive for around 50% and 80% of farmers in participation and expenses, respectively, for irrigation maintenance. This may be attributed to the fact that the households with un-irrigated land are more likely to contribute to the irrigation maintenance when the community size is larger, as shown in coefficient $\delta_4$ in block A and B of Table 4 as well as the positive group size effects for irrigated land ownership, i.e., the coefficient $\delta_5$, in block A of Table 4. In other words, irrigation maintenance may be interpreted as investments to public goods of irrigation quality, involving positive externalities arising from social networking. In contrast, more than 80% of households show the negative marginal effect of group size in the indirectly productive activities, which may be related to pure private goods.

Second, monetary contribution is less likely to cause the free rider problem than nonmonetary contribution in the case of both irrigation maintenance and
Table 5. **Two-Sample Kolmogorov-Smirnov Test**

| Test  | F(x): Expenses for irrigation maintenance | G(x): Expenses for ceremonies | F(x): Participation in irrigation maintenance | G(x): Participation in community work | F(x): Expenses for irrigation maintenance | G(x): Participation in irrigation maintenance | F(x): Expenses for ceremonies | G(x): Participation in community work |
|-------|------------------------------------------|------------------------------|----------------------------------------------|------------------------------------|------------------------------------------|----------------------------------------------|--------------------------------|-------------------------------------|
| Test 1|                                           |                              |                                              |                                    |                                           |                                              |                              |                                     |
|       | 0.000                                     |                              |                                              |                                    | 0.000                                     |                                              |                              | 0.049                               |
| Test 2|                                           |                              |                                              |                                    |                                           |                                              | 0.006                          | 0.000                               |
| Test 3|                                           |                              |                                              |                                    |                                           |                                              | 0.000                          | 0.000                               |
| Test 4|                                           |                              |                                              |                                    |                                           |                                              |                              | 0.049                               |

*** = p < 0.01, ** = p < 0.05, * = p < 0.1.

community events. Unlike labor contributions, monetary contributions involve collection of fees which can be easily tracked and verified, possibly leading to better enforcement of collective action. Also, the collective action problem in the case of nonmonetary contribution may be serious due to binding time allocation. Since nonmonetary contribution is made in labor contribution, labor contribution directly decreases time available for other activities. Because of this opportunity cost of labor contribution, the marginal effect may exhibit a similar pattern as in the case of pure private goods.

We can verify whether these differences in Figure 4 are statistically significant. To compare the pairwise CDFs among activities, we perform two-sample Kolmogorov-Smirnov tests. The results are reported in Table 5, which shows that these depicted CDFs are statistically different in the sense of the first-order stochastic dominance.

Also, using the median FO size as the threshold size, we divide the observations into larger and smaller FOs to estimate specification (3) of Table 4 separately and to compare the marginal effects. We find that free riding is more likely to occur in the smaller organizations—three activities, except for the participation in irrigation maintenance, present negative and smaller marginal effects in the smaller organizations. The differences are statistically significant at the 1% level.

V. Conclusion

In this study, we investigate the impact of group size on farmers’ decisions under four different modes of collective action. Besides the free rider problem predicted by the team production framework, we also examine social preference such as altruism and voluntary cooperativeness elicited by the artefactual field experiments. We combine the artefactual field experiment data with unique panel
data under a natural experimental situation in southern Sri Lanka where irrigation facilities were constructed under predetermined exogenous rules and farmers were randomly allocated to their land.

We find evidence of free riding by self-interested households with no landholdings. It is also shown that social preference explains the behavior in collective action. The pattern of collective action, however, differs significantly by mode of activity—action that is directly related to production is less likely to suffer from the free rider problem, which is widespread in the indirectly productive activities such as expenses for ceremonies and participation in community work. Finally, we find that the monetary contribution is less likely to cause free riding than non-monetary labor contribution for both irrigation maintenance and community events.

There are several possible promising research areas related to our study. It would be important to examine the effectiveness of farmer organizations and collective action in improving farm productivity and household welfare. Since the role of irrigation is in providing water even during dry seasons, dynamic outcomes such as production, income, and consumption smoothing should be studied carefully (Sawada et al. 2010). Finally, while this study finds heterogeneous contributions across types of collective actions, our framework does not necessarily identify the mechanism. Further studies on this issue will be required. Unlike labor contributions, monetary contributions involve collection of fees which can easily be tracked and verified, possibly leading to better enforcement of collective action.

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