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Social capital as an instrument for common pool resource management: a case study of irrigation management in Sri Lanka

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Abstract

Although social capital is considered to be a key instrument for common pool resource (CPR) management, its effect among heterogenous players such as upstream and downstream farmers along an irrigation canal is not clear. Using a combination of lab-in-the-field experiments to measure social capital and household survey data in a unique natural experimental setting, this study shows that upstream farmers with higher trust toward the downstream farmers are more likely to be satisfied with their water usage. This finding is consistent with the hypothesis that upstream farmers with higher trust demand less water and leave more water in a canal because they expect reciprocal behaviour from downstream farmers. Since the incentive structures of irrigation management closely resemble those of the standard experiments to measure social capital, this finding also provides a unique case study of the real-world relevance of these experiments.

JEL classifications: C93, O12, O13, Q15.

1. Introduction

Common pool resources (CPRs), characterized by non-excludability and rivalry in consumption, have been considered a subject to the 'tragedy of the commons' (Hardin, 1968). However, many case studies have shown that the cooperation needed to maintain CPRs can be achieved even in developing countries, where formal institutions are not necessarily highly developed (e.g. Ostrom, 1990; Aoki and Hayami, 2001). A key instrument for successful CPR management is social capital (e.g. Agrawal, 2001; Bowles and Gintis, 2002; Hayami, 2009).[1]

1 Cooperation in CPR management is often explained theoretically using simple repeated games (e.g. Baland and Platteau, 2000). Amid such research, Aoki (2001) shows theoretically that players co-operate in irrigation management even though they have an incentive to free ride, out of fear of being excluded from social exchanges such as mutual aid and social events (i.e. losing social capital).

Although the definition of social capital is still controversial, many studies agree on norms, trust, and social networks being important components (Coleman, 1988; Putnam, 1993; Ostrom, 1999; Durlauf and Fafchamps, 2005; Hayami, 2009). Of these, two important concepts are altruism and trust. Altruism is the degree of caring for others, which is often represented as a utility function in which the inputs are not only an individual's own payoff but also others' payoff (e.g. Becker, 1974). Trust is a behaviour of expecting some positive reciprocity from a partner, which also cannot be explained by motives of self-interest (e.g. Putnam, 1993). Though these components are expected to induce cooperation in CPR management, their effect among heterogeneous resource users remains an important topic to be explored (e.g. Bardhan and Dayton-Johnson, 2002).

Among the various types of heterogeneities, one specific to irrigation management is locational advantage and disadvantage in resource access. Upstream and downstream farmers differ in terms of their access to irrigation water: if upstream farmers use too much water, downstream farmers are deprived of their share. This type of heterogeneity can violate both equity among farmers and production efficiency in the whole area, resulting in irrigation management failure (e.g. Chakravorty and Roumasset, 1991; Ferguson, 1992; Ray and Williams, 2002). Consequently, this issue is important not only for academic purposes but also from a policy perspective.

This study aims to investigate the role of social capital in the irrigation water allocation problem between upstream and downstream farmers. Numerous empirical studies have focused on this topic, but there is no consensus on whether upstream and downstream asymmetry really impedes irrigation management. Based on observational data, several studies have found that a difference in water availability between upstream and downstream farmers leads to irrigation management failure (e.g. Wade, 1988; Tang, 1992; Fujiie *et al.*, 2005). Ostrom and Gardner (1993) show that the construction of headworks, which requires cooperation among all farmers along a canal, leads to better water allocation between upstream and downstream of an irrigation system in Nepal, whereas a modern irrigation system with permanent headworks may impede this cooperation. Meinzen-Dick *et al.* (2002) find that although the head or tail location in minor canals does not affect canal maintenance in India, it does affect collective lobbying for additional water demands. Nakano and Otsuka (2011) find that distance from the main channel has an inverted U-shaped relationship with the contribution to channel cleaning in Uganda. However, these survey-based analyses have not been able to directly identify the effect of social capital, due to the inherent difficulties in measuring it.

In addition to these analyses, there is a growing body of literature using economic experiments to analyse the upstream and downstream asymmetry. One strand of studies is CPR experiments which model real CPR management (Ostrom, 2006; Cardenas, 2011). Among these, one of the most relevant experiments is the irrigation game introduced by Cardenas *et al.* (2013), which combines a voluntary cooperation game to produce CPR (i.e. irrigation water), with resource extraction in a unidirectional order to incorporate upstream and downstream asymmetry. Without any treatment, experiments with villagers in Thailand and Colombia as well as with university students confirm that upstream players extract significantly more water than downstream players, although this unfair allocation diminishes after an extraction rule is enforced (Janssen *et al.*, 2011; Cardenas *et al.*, 2013). In contrast, several studies have shown that communication among players leads to better cooperation and more efficient water allocation among villagers in Colombia and Kenya (Cardenas *et al.*, 2010) as well as among student players (Holt *et al.*, 2012). Conducting the same game with Colombian farmers, Pfaff *et al.* (2015) illustrate that serious scarcity in the initial round can erode other-regarding preferences in subsequent rounds even when resources are abundant.

Another strand of experimental studies has analysed the problem of upstream and downstream asymmetry with standard economic experiments, regarding the experiments as water allocation between upstream and downstream farmers. For example, Jack (2009) uses a trust game played by Kenyan villagers and D'Exelle *et al.* (2012) use an ultimatum game played by Tanzanian villagers to analyse the cooperation between upstream and downstream farmers. However, both strands of studies analyse the behaviour in experimental settings, and comparison with actual CPR management remains an important issue to be addressed.

In order to overcome the limitations in both survey-based and experimental studies, this study combines standard household survey data and lab-in-the-field experiments (Gneezy and Imas, 2017) to elicit the level of social capital. This approach enables making an important contribution to the literature by showing the link between actual irrigation water allocation and experimentally measured social capital. Recent developments in experimental methods have enabled us to measure social capital quantitatively (e.g. Camerer and Fehr, 2004; Levitt and List, 2007; Cardenas and Carpenter, 2008). Following this trend, several studies find a positive correlation between experimentally measured social capital and cooperation in CPR management.[2] For example, Bouma *et al.* (2008) find that the results of a trust game and the participation in irrigation management are positively correlated in rural India. Fehr and Leibbrandt (2011) show that the results of a public goods game in fishing communities in Brazil are positively associated with the mesh size of the fishing nets, which is a measure of the conservation of resources. Kosfeld and Rustagi (2015) use a variant of a public goods game to elicit leader types in terms of the punishment rule and find that groups with leaders who emphasize equality and efficiency tend to have more young trees in forestry communities in Ethiopia. However, note that heterogeneity in resource accessibility such as upstream and downstream remains unaddressed in these studies.

Another contribution of this study is showing the link between standard economic experiments and actual economic transactions similar to these experiments. The incentive structure of irrigation water allocation for upstream farmers closely resembles the incentive structures in dictator and trust games, because the proposer (i.e. the upstream farmer) has full access to the resource, whereas the payoff of the partner (i.e. the downstream farmer) depends on the amount the proposer sends. Furthermore, in the trust game, receivers have the option of sending money back to the proposer, which is the equivalent of downstream farmers cooperating in irrigation canal management (Ostrom and Gardner, 1993; Jack, 2009) or some other, similar form of social exchange (Aoki, 2001). By showing the relationship between irrigation management and the results of dictator and trust games, this study can thus provide a unique case study on the real-world relevance of these games, an important issue that remains to be explored (Roe and Just, 2009).

2 In addition to CPR management, social capital measured by these experimental methods can predict actual economic outcomes such as the repayment rate in microcredit (Karlan, 2005), workers' earnings and productivity (Barr and Serneels, 2008; Carpenter and Seki, 2011), and household expenditure (Carter and Castillo, 2011).

Lastly, this study overcomes the potential, unobserved heterogeneities between upstream and downstream farmers. This study uses a unique data set from an irrigation project in southern Sri Lanka, collected by the Japan International Cooperation Agency (JICA). The study site has a unique natural experimental setting, in which the distribution of irrigated plots was partially exogenously determined. Because of this feature, the location along an irrigation canal is independent of other unobserved characteristics, which enables us to estimate the effect of social capital on irrigation water allocation between upstream and downstream farmers more clearly than in previous studies.

The rest of this paper is organized as follows. Section 2 describes the study site and its natural experimental situation, as well as the lab-in-the-field experiment data. Section 3 details the empirical strategy this study employs. Section 4 presents the descriptive statistics and main empirical results. The final section summarizes the study and offers concluding remarks.

2. Setting of the natural and field experiments

2.1 Study site and the natural experiment

This study uses a data set from an irrigation project in Sri Lanka originally compiled by JICA.[3] The study site is the Walawe Left Bank, located in southern Sri Lanka. The Sri Lankan government constructed the Uda Walawe reservoir between 1963–1967. This reservoir is located on the boundary between Sri Lanka's wet and dry zones, and the area's rainfall pattern is influenced by monsoon winds. Construction of the Left Bank Main Canal, which is the focus of this study, was launched in 1997 with Japanese ODA loans. By the end of 2008, almost every household in the study site had acquired access to irrigation facilities. The access to irrigation enabled farmers to cultivate paddy and other farming crops and their income increased significantly (Sellamuttu *et al.*, 2014). Thus, irrigation agriculture is the most important livelihood for most of the farmers in the study site, and water allocation is an important issue among them.

JICA (formerly the Japan Bank for International Cooperation [JBIC]) initiated a household survey in 2001 to assess the impact of the irrigation system. Its target was 858 households randomly selected from approximately 75,000 residents through a multi-stage random sampling procedure. JICA had conducted seven household surveys, and the sample size was scaled down to 193 households in the last two rounds. In addition to these surveys, they also conducted one field experimental session in March 2009 to measure the degree of social capital. The sample contained 268 farmers, including 188 from the last 193 sample households and 80 new households randomly selected from the area. Subsequently, JICA conducted a household survey across these 268 households with a similar questionnaire to that used in previous surveys. This study uses the data from the experiment and the latest household survey of these 268 samples.

The study site is divided into five blocks based on the timing of their access to irrigation: Sevanagala Irrigated, Sevanagala Rainfed,[4] Kiriibbanwewa, Sooriyawewa, and Extension Area. Each block contains a number of distribution canals (D-canals) that draw water from the main canal to distribute it to each farmland area. Each D-canal provides about 50 farm

3 See JBIC Institute (2007) for details.

4 There is no irrigation access in the Sevanagala Rainfed area because of topographic constraints. This study excludes individuals living in this area.

plots with irrigation water, for both paddy and other farming crops. In this data set, each household is assigned to one D-canal, and no D-canals extend across blocks. The water supply is controlled at each D-canal by the authorities, and water management within a D-canal is conducted by a farmers' organization (FO), which consists of all the farmers belonging to the D-canal. These FOs are also responsible for all irrigation management. Although management rules can differ across FOs, many of them adopt the *Murawathara* rule, where they specify on which day in a week a farmer can extract water. However, there is anecdotal evidence that a few farmers violate this rule or even try to get more water by damming the water flow in a canal, which decreases water accessibility for downstream farmers. Thus, there is potential for conflict over water between upstream and downstream. In addition to water allocation, the farmers have to engage in cleaning of both the dams and their own canals. Although there is no financial compensation for participating in this cleaning, some FOs fine those who do not participate. However, these fines are usually less than their daily wages. In this sense, farmers' cooperation is supported by non-monetary other regarding preferences such as altruism and reciprocity.

The study site possesses a unique, natural experimental setting as to allocation of irrigated land, which is suitable to identify upstream and downstream asymmetry from other types of heterogeneities. Since the study site was a newly irrigated area, the government invited settlement applicants on each canal construction. In the process of irrigated land allocation, a lottery-based allocation was employed for new settlers. In fact, of the original sample households, 48.88% answered that they did not have a chance to claim a preference for plot-level land. Lottery-based allocation was employed for 30.04% of the households. In contrast, re-settlers (i.e. those who had resided at the study site before the construction of the irrigation system) were allowed to select land from their former cultivation area. Many of these re-settlers were able to obtain their claimed plot without any procedure. Others were instead allocated a plot on a first come, first served basis; through negotiation with other farmers; or without any formal permission. However, even these re-settlers were not given the opportunity to choose which D-canals they would like to be assigned, let alone upstream or downstream locations. Thus, land allocation was exogenously determined at the D-canal level not only for new settlers but also re-settlers. Additionally, property rights to the irrigated plots were not given to the farmers until April 2009; therefore, farmers could neither sell nor collateralize their irrigated plots until then.[5]

This natural experimental setting provides an ideal situation to analyse the asymmetry between upstream and downstream. If land markets function properly, locational advantages and disadvantages, such as being located upstream or downstream of a canal, are reflected in land values, and thus cannot be identified from income or asset inequality (Bardhan and Dayton-Johnson, 2002). However, as the distribution of the irrigated plots was exogenously determined in the study site, albeit partially, this issue is not salient in this study. In order to show that the location within a canal is independent of income or wealth inequality, Figs 1 and 2 show the cumulative distribution functions of income and total irrigated plot size in 2009 by canal section. Although the difference in total plot size between the head and middle sections is marginally significant according to the combined Kolmogorov–Smirnov test (P-value $= 0.063$), no systematic differences were found in the

5 Although there is no information on the exchange of farm plots, there is little possibility of exchanging plots, because renting out the irrigated plot is prohibited and very rare in the data set.

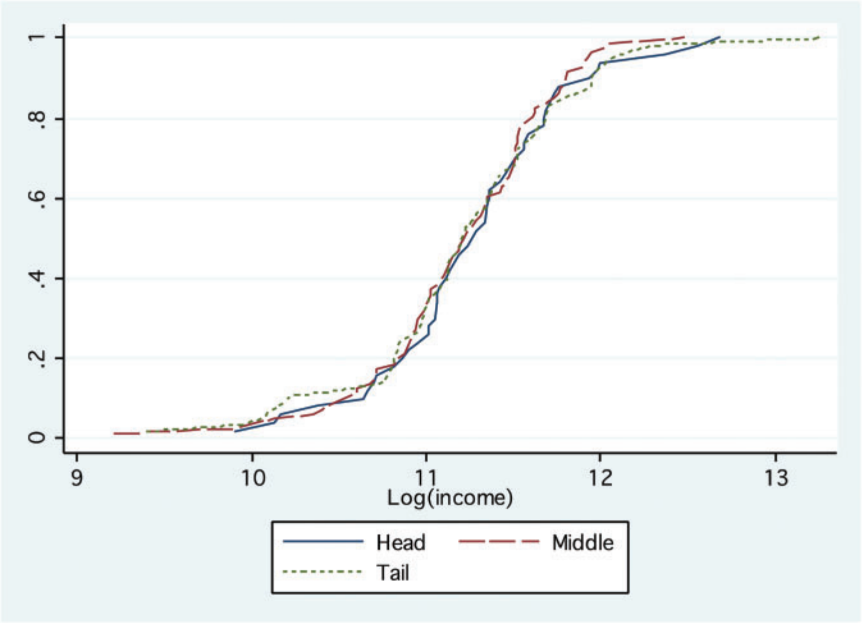

Fig. 1. CDF of log(income).

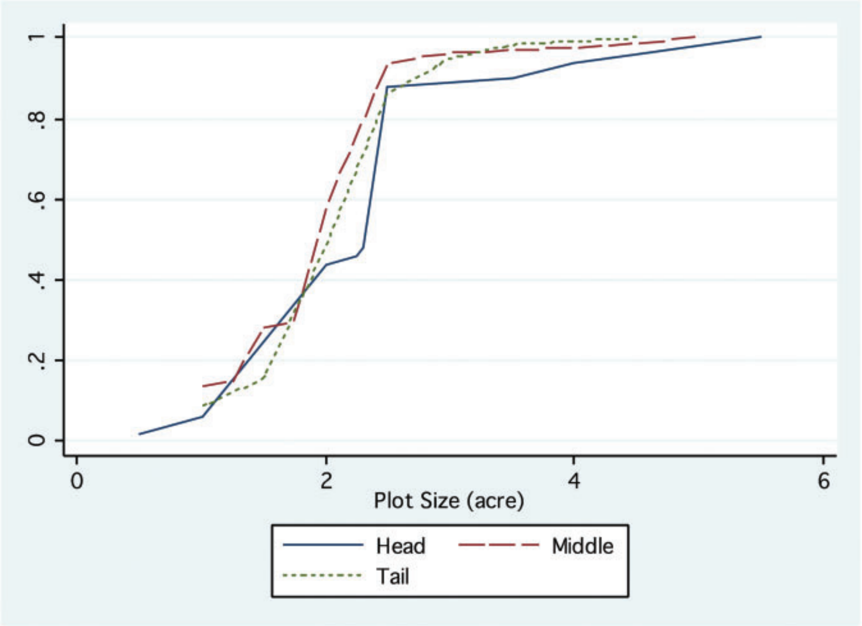

Fig. 2. CDF of total irrigated plot size.

other pairs for both variables.[6] These results confirm that no systematic differences in income or plot size exist between the head-end and the tail-end. Therefore, this study can address head and tail asymmetry through 'cleaner' data than that used in previous studies.[7]

Another important feature of the study site which is suitable for this study is that all respondents are Sinhala speakers and belong to the same religion. Although the ethnic conflict between the Sinhalese and the Tamils has been a serious problem in Sri Lanka, it is not necessary to consider how this problem may confound this study because the data are free of heterogeneity in terms of language and religion, which are important aspects of social heterogeneities (Bardhan and Dayton-Johnson, 2002).

2.2 Lab-in-the-field experiments

In March 2009, JICA conducted several lab-in-the field experiments with real money as a part of the data collection project. The experiments included dictator and trust games (Forsythe *et al*., 1994; Berg *et al*., 1995) to elicit the degree of social capital and dice game (Schechter, 2007) to elicit the degree of risk preference.[8] All participants went through all the experiments, but they were informed that the final payment would be based on the result of a randomly chosen game. The sample consisted of the above-mentioned 268 farmers randomly selected from the survey area. Although the originally invited participants were either household heads or members, seven households could not send their representative to the experiment and sent instead a son or daughter who lived in another city. Because these agent players are irrelevant from the perspective of actual irrigation management, their observations were excluded from the analysis.[9]

The dictator game is played in pairs: a sender and a receiver. A sender receives the initial endowment (E) and decides how much of the endowment to send to the receiver (x). The receiver has no option but to accept the amount sent by the sender. Thus, the final payoffs for the sender and the receiver are ($E-x$, x). If the sender is self-interested, there is no reason to send a positive amount to the partner. Therefore, the sent amount is interpreted as the degree of altruism (Camerer and Fehr, 2004; Levitt and List, 2007).

The trust game is also played by a pair of people: a trustor and a trustee. A trustor receives the initial endowment (E) and decides how much of the endowment to send to the trustee (x). The amount received by the trustee is tripled by the experimenter. Then the trustee decides how much to send back to the trustor (y). Thus, the final payoffs for the trustor and the trustee are ($E-x+y$, $3x-y$). Note that if a trustee is self-interested, y should be 0, and foreseeing this, a self-interested trustor would choose to send nothing ($x=0$). Thus, x and y are interpreted as the degree of trust and trustworthiness, respectively (Camerer and Fehr, 2004; Levitt and List, 2007).

6 The t-tests for the difference in income and irrigated plot size between canal head and tail are both insignificant, with p-values of 0.68 and 0.22, respectively.

7 The balance tests in the Online Appendix also confirm that no systematic difference exists among canal locations within a D-canal.

8 Detailed instructions are available in the Online Appendix.

9 The share of these agent players is 2.61%. Whether a household sent an agent player is not significantly correlated with household characteristics, confirming that the sample selection issue is not salient.

In the actual implementation, the participants played both roles in both games.[10] The initial endowment in both games was LKR 500, which is the average one-day wage in the study area. Each person, as a sender/trustor, played the games with four types of partners (six partners in total): three non-anonymous players in the same D-canal, an anonymous player in the same D-canal, an anonymous player in the same block, and an anonymous player in a different block. The three non-anonymous partners were the same in both games. The experiment employed strategy method: the participants decided the amount $x \in \{0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500\}$ to the six potential partners by filling in the form.[11] When all participants had finished their decision making as senders/trustors, they were paired with one of the partners for the actual transaction. However, throughout all the experiments, they were not informed with whom they were actually matched. They were informed about only the amount they had received from one of their potential partners. In the trust game, each person as a trustee decided how much money to send back to their four types of potential partners. Since all the participants were paired with only one of their potential partners, they decided on the amount they wished to send to each of the four types of partners as if the tripled amount they received had been from them.[12]

An important setting in these experiments is that we can measure the degree of altruism and trust toward a specific person in the non-anonymous partner setting. Since these non-anonymous partners were selected from the same D-canal, most of them knew their partners through daily interactions and could identify whether they were located in upstream or downstream area with reference to themselves. Therefore, we can elicit the level of altruism and trust toward their upstream and downstream farmers by using the partner's relative position within a canal.

In addition to these games, a dice game based on Schechter (2007) was conducted to measure participants' risk attitude. Players were given LKR 500 as an initial endowment and could choose how much of this money they wanted to invest. The player then rolled a die with a different colour on each of the six faces to determine the investor payoffs such that $\{0, 0.5x, x, 1.5x, 2x, 2.5x\}$, where x is the invested amount. Since a higher investment amount means higher preference for a risky choice, x can be interpreted as their risk preference.

Using the same data set, Aoyagi *et al.* (2014) investigate the determinants of particularized trust, which is trust toward a specific person. They find that longer access to the irrigation canal has a positive impact on particularized trust, suggesting that embeddedness with respect to an irrigation infrastructure leads to better communication and cooperation among neighbours. This implies the endogeneity of altruism and trust toward specific

10 Burks *et al.* (2003) show that playing both roles reduces the sending amount in the trust game. Thus, altruism and trust measured in this study might be at the lower bounds of the true parameters. This caveat applies when interpreting the results.

11 For the three non-anonymous partners, their pictures and names were printed on the answer sheet so that the participants could identify their game partner. The results of the strategy method are known to be comparable with those of the standard direct-response method (Brandts and Charness, 2011).

12 Because of this feature, the amount sent back might not capture the actual degree of trustworthiness as measured in other studies. For this reason, this study does not investigate the effect of receivers' behaviours in the trust game.

partners within the same D-canal, which calls for the instrumental variable approach described in the following section.

3. Empirical strategy

3.1 Theoretical background

In actual irrigation management, it is difficult to charge an irrigation water usage fee based on individual water usage amounts. Because of this feature, self-interested farmers demand more water as long as its marginal productivity is positive, which results in a water shortage in the downstream area.

In contrast to this model, according to utility functions with altruism or trust, upstream farmers who care for others tend to demand less irrigation water because there is a utility gain from leaving water for downstream farmers (e.g. Hayami, 2009; Velez *et al.*, 2009).[13] If the upstream farmers' motives are based on altruism, they achieve higher utility by leaving more water for downstream farmers as long as the marginal utility gain from the improvement of downstream farmers' payoffs is higher than the marginal loss of utility from giving up part of their own extraction. If their motives are based on trust, i.e. they expect a positive return from downstream farmers, they have an incentive to leave more water in the canal as long as the expected marginal return is higher than the marginal loss of utility. Therefore, a higher level of altruism or trust leads to a lower demand for irrigation water compared with that in the model based on self-interest.

These two motives lead to similar expected results, i.e. demanding less water than in the self-interest model and leaving more water for downstream farmers. Although the extent of this effect depends on the specification of the model, a discernible difference between trust and altruism is whether the senders expect positive reciprocity. In the case of irrigation, reciprocal behaviour from downstream farmers can take the form of participation in irrigation maintenance or other social exchanges.

3.2 Identification strategy

The aim of this study is to test whether higher altruism or trust toward downstream farmers leads to lower irrigation water demand, which results in higher water availability in downstream area. For this purpose, the most straightforward way of measuring water demand is to measure the amount of water used by a farmer. However, such direct measurement of individual water usage is known to be very difficult (Schoengold and Zilberman, 2006). Instead, this study uses subjective satisfaction with their irrigation water usage as an outcome variable. In the survey, the respondents answered the following question: 'In the Maha (north-east monsoon season that extends from October to March) 2008–2009 season, could you get as much water as you wanted when you needed it?' If they responded negatively, they were asked 'How much water (as a percentage) did you get compared to the amount you wanted during the Maha 2008–2009 season?' As such, the former answer is a binary variable that indicates whether the respondents were satisfied, whereas the latter is a continuous variable that shows the percentage of water they used compared with the amount they wanted.[14] Note that these self-reported variables are not necessarily proxies of

13 Velez *et al.* (2009) also show that a simple self-interested utility function cannot adequately explain the motivation for CPR management.

14 The percentage satisfaction variable is noted as 100 if respondents answered that they were satisfied with the amounts of water received.

scarcity per se, but rather reflect whether their irrigation water supply met the demanded level: if demand for irrigation water exceeds the level of supply, a farmer will not be satisfied. Therefore, if the water supply level is controlled, farmers with a higher water demand would tend to be less satisfied with the level of water availability.[15]

As noted above, upstream and downstream farmers face different incentive structures on water usage. Upstream farmers with higher social capital decide how much water to use while considering downstream farmers. In contrast, the effect of social capital is expected to be significantly less salient for downstream farmers, because the number of farmers who extract water after them is small. Therefore, although social capital is expected to have a significantly positive effect on satisfaction for upstream farmers, its effect for downstream farmers is unclear. To take this asymmetry into account, it is important to distinguish whether the partner in the dictator and trust games is in upstream or downstream area relative to the player.

Because the data set contains the results of the games for three non-anonymous partners per player in the dictator and trust games, the respective data are stacked for each observation.[16] In each observation, players can determine whether their partner is located upstream/downstream relative to themselves. The location within a D-canal is classified into head-end, middle, and tail-end, depending on the distance from the headworks. Because samples were selected randomly from each D-canal, the cross terms of the results of the games and whether the partner in the games is upstream/downstream can capture the mean level of altruism and trust toward the upstream/downstream farmers.

Considering these issues, this study estimates the following regression model:

$$Y_i = \alpha + \beta_1 SC_{ij} + \beta_2 vs\_downstream_{ij} \times SC_{ij} + \beta_3 vs\_upstream_{ij} \times SC_{ij} + \gamma X_i + DC_i + \varepsilon_{ij}, \quad (1)$$

where Y_i is the outcome of the satisfaction variables (binary or percentage), SC_{ij} is the amount sent from player i to partner j in the dictator or trust game which represents the level of altruism or trust toward j, and $vs\_downstream_{ij}$ and $vs\_upstream_{ij}$ are binary variables that take the value 1 if j is located downstream or upstream relative to i (i.e. $vs\_downstream_{ij} = 1$ if $(i, j) \in \{(head, middle), (head, tail), (middle, tail)\}$ and $vs\_upstream_{ij} = 1$ if $(i, j) \in \{(tail, middle), (tail, head), (middle, head)\}$). The base category is whether the partner is at the same location within a D-canal (i.e. $(i, j) \in \{(head, head), (middle, middle), (tail, tail)\}$). Therefore, β_2 and β_3 capture the effect of altruism or trust toward downstream and upstream farmers, respectively, while β_1 captures those effects toward farmers in the same section within a canal. Note that $vs\_downstream_{ij}$ and $vs\_upstream_{ij}$ themselves should not affect the level of satisfaction, because these variables only represent whether

15 Another approach would be to estimate the effect of upstream farmers' altruism and trust on downstream farmers' satisfaction. However, this study selected 3.3 farmers from each D-canal with 50 farm plots on average. Thus, the effect of water usage by these upstream farmers who participated in the experiment on the downstream farmers' satisfaction level is too small to be detected by econometric analysis. For this reason, this study exploits the above-mentioned approach.

16 Basically, the total sample size is three times the number of relevant participants (i.e. rice farmers who participated in the experiment by themselves or sent household members to participate in the experiment). However, the actual sample size is slightly smaller because the cases of relevant players with irrelevant partners are also excluded from the analysis.

the randomly selected partners in the experiment are located upstream or downstream, and thus are irrelevant to the actual irrigation water usage. For this reason, these variables are included only as interaction terms to elicit the degree of altruism and trust toward upstream and downstream farmers. X_i is a set of other control variables, and DC_i is a set of binary variables corresponding to the D-canal to which i belongs. These D-canal fixed effects control for the water supply level as well as all the other differences within the CPR user group, including differences in rules for irrigation management. ε_{ij} is the measurement error of the subjective satisfaction variable. Note that observations for each player are not independent. Therefore, standard errors need to be adjusted for correlation within an individual.

The main parameter of interest is β_2. If farmers optimize their water extraction level so as to care for their downstream counterparts, their demand should be lower, which means that they are more likely to be satisfied. Therefore, the testable hypothesis is whether β_2 is positive. Additionally, the games only capture the incentive structure of the upstream farmers. Thus, no predictions can be made regarding the sign of β_3, which captures altruism or trust toward head-enders. After controlling for whether the partner is upstream or downstream, β_1 captures the effects of altruism and trust toward farmers who are in the same canal section, which also corresponds to the situation of the tragedy of the commons, though not as seriously as that between upstream and downstream.

In using the trust game as a social capital variable, it is necessary to control for altruism and risk attitude because the behaviour of the first mover in a trust game is confounded by altruism and risk attitude (e.g. Cox, 2004; Schechter, 2007). For this reason, the results of the dictator game and the dice game are included as control variables.

A potential issue in estimating model (1) by ordinary least squares (OLS) is that it ignores reverse causality between social capital and satisfaction. Higher social capital is assumed to lead to better water allocation and higher satisfaction with water usage, because social capital decreases water demand. However, social capital itself also reflects the results of water allocation. In other words, not only does social capital affect satisfaction with water usage but this satisfaction in turn may also affect social capital, though the effect is an empirical question. Additionally, it is possible that the social capital variables are correlated with unobserved factors, such as feelings of frustration or deprivation toward specific partners. Consequently, correlation, but not necessarily causality, can be estimated by OLS.

To address these limitations, this study uses dictator and trust games toward anonymous partners in a different D-canal as instrument variables (IVs). It is natural to assume that both cases share the players' inherent altruism or trust and that there is a positive correlation between them. In addition, because irrigation water is managed at the D-canal level, the water allocation problem does not occur across different D-canals. Therefore, the results for water allocation and the respective satisfaction with it do not affect altruism or trust toward those in different D-canal areas.[17] Because experiment participants were randomly selected from each D-canal area, whether the partner is an upstream/downstream farmer was also determined exogenously. Therefore, cross terms between these variables and altruism/trust toward a member of another D-canal also served as valid IVs.

17 It is possible that the use of irrigation water increases agricultural income, which results in higher amounts being sent in the dictator and trust games with an anonymous partner from a different D-canal. However, these variables are not significantly correlated with income even when controlling for other household characteristics.

Table 1. Sampling structure

Block	D-canal	Original sample size	Sample size of this study
Sevanagala Irrigated	2	28	16
Sevanagala Rainfed	0	12	0
Kiriibbanwewa	6	32	20
Sooriyawewa	6	40	34
Extension Area	24	156	119
Total	38	268	189

Note: The households in Sevanagala Rainfed are excluded from this study because there is no irrigation in this block. Also, households (1) who do not cultivate paddy, or (2) who could not send their family member to the experimental sessions are excluded for this study.
Source: Author's calculations.

In the estimation of model (1), this study limits the sample to farmers who cultivated paddy fields (rice) on the irrigated land, for the following reasons. First, paddy-grown rice is the major crop in this area, cultivated by 78% of the sample households. Second, paddies require much more water during the growing season compared with other crops. The water allocation problem is thus most serious for paddy cultivation. Third, compared with other crops, paddy is highly sensitive to water shortages but relatively tolerant to overabundance. For this reason, reallocating water from upstream to downstream can potentially improve efficiency, especially for this crop (Ostrom, 1990). The comparison between the original and the final sample size in each block is shown in Table 1.

One caveat relating to the data is that there are some farmers who own more than one irrigated plot. Although the data set contains water satisfaction levels for each plot, it is impossible in these cases to identify what crops were being cultivated on each plot. This study primarily focuses on the main plot, which is defined as the largest irrigated plot possessed by each household, because respondents tended to cultivate paddy on larger plots.[18]

4. Data and empirical results

4.1 Descriptive analysis

Table 2 illustrates the descriptive statistics used for the main empirical study. Panel A displays household characteristics. The binary variable for satisfaction in the main plot shows that 67% of the sample answered they were satisfied with their water usage; in other words, one-third of the respondents were not satisfied with the amount of water available. This indicates that there is not enough irrigation water for everyone to have a sufficient amount, highlighting the need for coordination of water allocation.

Panel B of Table 2 shows the results of the lab-in-the-field experiment, which are shown in the share of the amount sent to the partners. It can be seen that the share of the amount sent decreases as the social distance between partners increases, which is consistent with previous studies (e.g. Hoffman *et al.*, 1996; Leider *et al.*, 2009; Etang *et al.*, 2011) and

18 Unfortunately, there is no direct way to test this assumption. However, since the paddy field requires a larger plot with better irrigation access, it is not unrealistic to assume that farmers cultivate paddy on their largest irrigated plot. The following models are also estimated using the averages of satisfaction for each plot weighted by plot size as alternative measures. These findings confirmed that the qualitative results remained virtually unchanged.

Table 2. Descriptive statistics

	Obs.	Mean	Std. Dev.
Panel A: Household characteristics			
Satisfaction (binary): main plot	187	0.668	0.472
Satisfaction (%): main plot	187	88.824	18.807
Location			
Head (base category)	189	0.265	0.442
Middle	189	0.429	0.496
Tail	189	0.307	0.462
Log (yield (kg/ha))	189	1.101	0.737
Log (plot size)	189	0.683	0.295
Household head	189	0.725	0.448
Age of household head	188	52.457	10.571
Female household head	188	0.090	0.288
Education of household head	185	6.222	3.254
Re-settler	189	0.460	0.500
Number of members in non-agriculture	189	3.598	1.719
Years of access to D-canal	187	9.770	8.919
Years of Experience in Farming	187	30.861	11.239
Panel B: Lab-in-the-field experiment			
Vs_downstream	552	0.312	0.464
Vs_upstream	552	0.310	0.463
Dictator game (sending share)			
(a) Same D-canal (non-anonymous)	552	0.321	0.222
(b) Same D-canal (anonymous)	552	0.274	0.210
(c) Different D-canal, same block (anonymous)	552	0.205	0.197
(d) Different block (anonymous)	552	0.160	0.184
Trust game (sending share)			
(a) Same D-canal (non-anonymous)	552	0.423	0.261
(b) Same D-canal (anonymous)	552	0.320	0.240
(c) Different D-canal, same block (anonymous)	552	0.257	0.252
(d) Different block (anonymous)	552	0.219	0.237
Dice game (sending share)	552	0.412	0.239

Note: For all variables in logarithmic form, 0.01 is added before taking the log.
Source: Author's calculations.

findings on in-group favouritism in social psychology literature (e.g. Tajfel *et al.*, 1971). Assuming additive separability, the differences between (a) and (b), (b) and (c), and (c) and (d) show the effect of whether the partner is identified, the effect of sharing the same D-canal, and the effect of living in the same block, respectively.

Table 3 shows the average satisfaction levels by canal section. The sample size differs from that in Table 2 because this table uses observations before stacking for artefactual experiment data. Regarding the binary satisfaction variables, the satisfaction level decreases from the head-end to the tail-end. Although the satisfaction percentage levels for the main plot increase slightly from the middle to the tail, there is a clear difference between the head and the middle and between the head and the tail.[19] The last column shows the t-value of

19 The increase from the middle to the tail-end is statistically insignificant ($p = 0.93$).

Table 3. Satisfaction level of irrigation water usage by canal section

	Mean			*t*-value
	Head	Middle	Tail	(head vs tail)
Sample size	50	80	57	
Satisfaction (binary)	0.76	0.663	0.596	1.809**
Satisfaction (%)	92.3	87.438	87.719	1.415*

Note: One-sided *t*-test. ** and * indicate that $p < 0.05$ and $p < 0.1$, respectively.
Source: Author's calculations.

the one-sided test (i.e. whether the mean of the head-enders' satisfaction levels is higher than the corresponding value for the tail-enders). All these results show significant differences, implying that downstream farmers possibly face a locational disadvantage in water availability.

4.2 Main regression analysis

Before investigating the effect of social capital on irrigation water allocation, model (1) is estimated without social capital variables to test the locational disadvantage of tail-enders conditional on household characteristics. Note that this specification corresponds to the self-interested model, which can serve as a benchmark. Columns (1) and (2) in Table 4 show the results of this estimation. The dependent variables are binary satisfaction in column (1) and percentage satisfaction in column (2). The observations are not stacked, because the results of the games are not included in the regression. The coefficients on tail-end dummies are both negative and significant in (1), suggesting that downstream farmers tend to be less satisfied with their water usage compared with the base category (i.e. head-enders); thus, there is a potential difference in water availability between upstream and downstream. Those who have more years of access to the current D-canal tend to be less satisfied with their water usage. Re-settlers, who could claim their preference of irrigated plots when they settled and did not go through a lottery-based plot allocation, are not necessarily satisfied or dissatisfied with their water usage. The number of household members in non-agricultural work, which captures the effect of the exit option (e.g. Bardhan, 2000; Fujiie *et al.*, 2005; Kajisa *et al.*, 2007; Nakano and Otsuka, 2011), is also insignificant. Note that these results are also unconditional on social capital variables, which is often the case with studies that only use observational data. Therefore, whether this significant effect of location within irrigation canals holds even after controlling for social capital is an important question.

Columns (3) and (4) show the estimation results using altruism measured by the dictator game as a type of social capital, and columns (5) and (6) show the results using trust measured by the trust game. The signs of the effect of altruism and trust toward downstream farmers are positive, and it is significant when the dependent variable is satisfaction level measured in percentage. This is consistent with the hypothesis that upstream farmers' altruism and trust lower their water demand, resulting in higher satisfaction level among upstream farmers. In contrast, the coefficients on the dictator and trust games themselves and their interaction with whether the partner is upstream are insignificant, implying that altruism or trust toward people in the same part of the canal or downstream does not affect satisfaction.

Table 4. Effect of altruism and trust on satisfaction level of water usage

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV
Type of social capital	NA	NA	Altruism	Altruism	Trust	Trust	Altruism	Altruism	Trust	Trust
Dependent variable	Binary	%	Binary	%	Binary	%	Binary	%	Binary	%
Dictator game			−0.003	3.084	−0.025	6.463	0.036	10.749	−0.512	3.609
			(0.136)	(5.601)	(0.151)	(5.723)	(0.266)	(11.009)	(0.576)	(21.161)
Vs_downstream ×			0.001	5.613*			0.086	7.288		
dictator game			(0.103)	(3.313)			(0.127)	(4.959)		
Vs_upstream ×			−0.121	−4.440			−0.270	−9.546		
dictator game			(0.115)	(4.202)			(0.168)	(6.983)		
Trust game					0.036	−2.080			0.664	12.247
					(0.120)	(4.995)			(0.521)	(18.369)
Vs_downstream ×					0.076	5.513**			0.227*	10.694**
trust game					(0.076)	(2.584)			(0.116)	(4.199)
Vs_upstream × trust game					−0.049	0.828			−0.202	−4.684
					(0.089)	(3.654)			(0.151)	(5.253)
Dice game					−0.168	−9.520			−0.232	−13.385**
					(0.154)	(5.898)			(0.164)	(6.368)
Middle	−0.128	−3.042	−0.104	−1.095	−0.072	−0.362	−0.064	−0.062	−0.008	2.160
	(0.087)	(3.178)	(0.081)	(2.948)	(0.085)	(3.090)	(0.081)	(2.957)	(0.094)	(3.208)
Tail	−0.207**	−2.616	−0.174*	0.321	−0.150*	−0.153	−0.104	2.505	−0.050	3.984
	(0.101)	(3.545)	(0.097)	(3.245)	(0.090)	(3.148)	(0.100)	(3.592)	(0.108)	(3.854)
Log (plot size)	−0.064	−4.157	−0.069	−4.308	−0.080	−4.620	−0.066	−4.206	−0.136	−5.960
	(0.124)	(5.086)	(0.109)	(4.428)	(0.111)	(4.328)	(0.102)	(4.154)	(0.121)	(4.535)
Household head	0.082	0.145	0.072	0.208	0.076	0.217	0.075	0.625	0.107	1.397
	(0.102)	(3.600)	(0.092)	(3.225)	(0.091)	(3.230)	(0.086)	(2.984)	(0.087)	(3.081)
Age of household head	−0.000	0.000	0.000	0.007	0.001	0.061	0.000	0.006	0.001	0.072
	(0.006)	(0.210)	(0.005)	(0.185)	(0.005)	(0.191)	(0.005)	(0.174)	(0.005)	(0.180)

(continued)

Table 4. Continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	OLS	OLS	OLS	OLS	OLS	IV	IV	IV	IV
Type of social capital	NA	NA	Altruism	Altruism	Trust	Trust	Altruism	Altruism	Trust	Trust
Dependent variable	Binary	%	Binary	%	Binary	%	Binary	%	Binary	%
Female household head	0.103	1.196	0.109	1.125	0.072	−0.706	0.108	1.124	0.007	−2.735
	(0.144)	(6.489)	(0.127)	(5.773)	(0.130)	(5.779)	(0.121)	(5.325)	(0.128)	(5.716)
Education of household	0.019	0.625	0.021*	0.659	0.020*	0.610	0.021**	0.609	0.025**	0.645
head	(0.012)	(0.491)	(0.011)	(0.453)	(0.011)	(0.446)	(0.010)	(0.417)	(0.012)	(0.453)
Re-settler	−0.025	−0.143	−0.013	0.331	−0.009	0.650	−0.018	0.162	0.003	0.842
	(0.076)	(2.946)	(0.068)	(2.552)	(0.068)	(2.530)	(0.065)	(2.416)	(0.066)	(2.407)
Number of members in	0.015	1.281	0.014	1.197	0.013	1.109	0.015	1.285	0.012	1.162
non-agriculture	(0.022)	(1.009)	(0.019)	(0.877)	(0.020)	(0.883)	(0.018)	(0.824)	(0.019)	(0.820)
Years of access to D-canal	−0.012**	−0.290	−0.012**	−0.295	−0.012**	−0.257	−0.012**	−0.326	−0.012**	−0.300
	(0.006)	(0.263)	(0.006)	(0.237)	(0.006)	(0.244)	(0.005)	(0.222)	(0.006)	(0.237)
Years of Experience	0.001	0.098	0.001	0.079	−0.000	0.025	0.000	0.070	−0.001	−0.017
in Farming	(0.005)	(0.175)	(0.004)	(0.156)	(0.004)	(0.159)	(0.004)	(0.149)	(0.004)	(0.156)
D-canal dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
First stage F-stat										
Dictator game							17.23***	17.23***	24.32***	24.32***
Vs_downstream × dictator game							39.06***	39.06***		
Vs_upstream × dictator game							25.95***	25.95***		
Trust game									24.24***	24.24***
Vs_downstream × trust game									68.39***	68.39***
Vs_upstream × trust game									50.42***	50.42***
Observations	179	179	523	523	523	523	523	523	523	523
R-squared	0.426	0.429	0.423	0.422	0.427	0.430	0.363	0.399	0.363	0.399

Note: Robust standard errors in parentheses for (1)—(2), and clustered standard errors in parentheses for (3)–(10). $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Source: Author's calculations.

Interestingly, once social capital variables are controlled for, the coefficients on the middle and tail dummies are not significant. This indicates that tail-enders are not necessarily less satisfied with water usage and, therefore, irrigation water is being satisfactorily allocated between upstream and downstream. Thus, the negative sign on the location variable in the benchmark models reflects bias from omitting the social capital variable. Other qualitative results are largely consistent with columns (1) and (2), except for the positive effect of education in columns (3) and (5).

Note that the results in columns (3)–(6) do not control for the reversed causality resulting from the effect of satisfaction with their irrigation water usage on the level of social capital. In order to incorporate this issue, the remaining columns show the estimation results using the IV approach. Columns (7) and (8) show the IV estimation results using altruism measured by the dictator game, and columns (9) and (10) show those using trust measured by the trust game. The main parameter of interest, the effect of altruism toward downstream farmers is no longer significant, though the signs are positive. In contrast, the effect of trust toward downstream farmers has a significantly positive effect on satisfaction level, regardless of whether it is measured in binary or percentage. Since the difference between altruism and trust is whether they expect positive reciprocity from the partner, this result implies that there are some positive returns from downstream farmers. This issue is examined in the following subsection. Other qualitative results remain virtually unchanged from the OLS estimations, except for the significantly negative effect of risk preference measured by the dice game, implying that risk-seeking farmers tend to demand more water deviating from the cooperative behaviour.

The comparison between the results of the OLS estimations and those of the IV estimation is also informative to understand the relationship between social capital and irrigation water usage. The magnitude of the coefficients on the dictator and trust game variables is larger in the IV estimation than in the OLS estimation, indicating the existence of downward bias in the OLS estimates resulting from the reversed causality. The sign of the reversed causality bias is determined by the sign of $\alpha_2/(1-\alpha_1\alpha_2)$, where α_1 denotes the true coefficient on the variable of interest in the main specification and α_2 denotes the corresponding true coefficient in the reversed regression (Basu, 2015). Assuming the validity of the instruments, positive IV estimates imply $\alpha_1 > 0$. Therefore, downward bias implies $\alpha_2 < 0$ or $\alpha_2 > 1/\alpha_1$. Considering the mean values of the satisfaction levels and altruism and trust in Table 2, $\alpha_2 > 1/\alpha_1$ is rather unlikely, albeit not theoretically impossible.[20] For this reason, the effect of the satisfaction level on altruism and trust is expected to be negative.

This negative effect is consistent with previous studies suggesting that collective actions are likely to take place when resources are scarce (Hayami, 2009). This is because scarcity of resources requires coordination among players, which leads to social capital being enhanced. In addition, Ostrom (2009) argues that the relationship between resource scarcity and CPR management is non-linear: some scarcity is necessary for collective action, whereas there is no room for collective action when a resource is already exhausted or

20 For example, for Column (9) in Table 4, $1/\alpha_1$ implies that $\alpha_2 > 4.405$. Since the mean value of *vs_downstream* $\times$ *trust game* is 0.132, the average magnitude of the effect on the satisfaction level should be larger than 0.581, if this is the case. However, this value is somewhat unrealistic because the mean value of the satisfaction level is 0.668.

very abundant.[21] In fact, previous studies using either observational data or economic experiments also confirm the positive relationship between (mild) resource scarcity and cooperation in irrigation management (e.g. Fujiie *et al*., 2005; Nakano and Otsuka, 2011; D'Exelle *et al*., 2012; Pfaff *et al*., 2015). Therefore, the negative effect of the satisfaction level on altruism and trust is in line with these interpretations, though it does not necessarily negate other possibilities.

4.3 Upstream farmers sample analysis

The results in the previous subsection, namely, that trust toward downstream counterparts positively affects the satisfaction level of upstream farmers, are consistent with the main hypothesis. However, it is also informative to test the hypothesis with upstream farmers alone, since the main hypothesis is based on the incentive structure affecting only upstream farmers. Table 5 shows the IV estimation results. The first two columns show the effect of altruism and the last two columns the effect of trust. Because the samples are restricted to upstream farmers (i.e. those who play the games with players in downstream areas relative to themselves), the results of the dictator and trust games capture the effect of altruism and trust toward their downstream farmers. In this specification, altruism toward downstream farmers has a significantly positive effect on satisfaction. Consistent with previous results, trust also shows a positive effect. These results confirm that higher altruism and trust toward downstream farmers leads upstream farmers to require less irrigation water and makes them more likely to be satisfied with their usage, which can lead to higher availability of irrigation water in the downstream area.

4.4 Validity of subjective satisfaction measure

The next concern is the validity of the subjective assessment of water usage level. The dependent variables used so far concern the subjective assessment of each farmer's water usage level. Thus, it is necessary to show the link between the satisfaction level variables and actual agricultural productivity. Another concern is the possibility of interpreting the results differently: people with higher social capital tend to be satisfied simply because they extract more water, and consequently, they enjoy higher productivity. If this is the case, the significantly positive coefficient on altruism and trust toward downstream counterparts is spurious, because productivity is omitted from the equation.

To address these concerns, eq. (1) is re-estimated by including the yield of paddy (kg/ha) during the same period. Table 6 shows the results of this estimation. Yield positively correlates with water usage and is significant in columns (2) and (4), where the dependent variable has more information than the binary one, confirming the validity of the subjective measures of the satisfaction level. However, the estimation results of this variable cannot be interpreted as causality, because it is highly endogenous and prone to measurement errors, which can result in attenuation bias. The main parameters of interest, namely, altruism and trust toward downstream farmers, remain virtually unchanged from Table 4. If the positive connection between satisfaction and social capital in the previous results did in fact result from the effect of higher income or higher productivity, this connection would have vanished once productivity is controlled for. Thus, the results are more consistent with the original hypothesis that trust toward downstream counterparts leads to better water allocation.

21 In fact, several studies show that severe resource scarcity can result in self-interested behaviour outside of resource management (Miguel *et al*., 2004; Miguel, 2005; Mehlum *et al*., 2006; Bignon *et al*., 2017).

Table 5. Effect of altruism and trust on satisfaction level of water usage (upstream farmers only)

	(1)	(2)	(3)	(4)
	IV	IV	IV	IV
Type of social capital	Altruism	Altruism	Trust	Trust
Dependent variable	Binary	%	Binary	%
Dictator game	0.450	24.379*	−0.008	3.066
	(0.283)	(12.485)	(0.533)	(19.490)
Trust game			0.993*	43.061**
			(0.594)	(20.269)
Dice game			−0.894***	−34.749***
			(0.235)	(8.988)
Middle	−0.030	−0.878	0.056	2.235
	(0.075)	(3.451)	(0.105)	(4.638)
Log (plot size)	−0.034	−9.988	−0.227	−18.684
	(0.183)	(9.308)	(0.280)	(13.168)
Household head	0.072	−1.845	0.129	0.483
	(0.095)	(3.823)	(0.109)	(4.611)
Age of household head	−0.003	−0.044	−0.001	0.006
	(0.006)	(0.268)	(0.008)	(0.331)
Female household head	0.162	3.702	−0.061	−5.572
	(0.197)	(8.974)	(0.266)	(12.396)
Education of household head	0.010	0.483	0.002	0.203
	(0.012)	(0.513)	(0.014)	(0.503)
Re-settler	−0.037	2.691	−0.031	3.096
	(0.074)	(2.838)	(0.086)	(3.661)
Number of members in non-agriculture	0.027	1.118	0.016	0.682
	(0.020)	(0.807)	(0.023)	(0.907)
Years of access to D-canal	−0.011	−0.358	−0.004	−0.068
	(0.008)	(0.330)	(0.011)	(0.432)
Years of Experience in Farming	0.008	0.399	0.003	0.186
	(0.006)	(0.246)	(0.006)	(0.283)
D-canal dummies	YES	YES	YES	YES
First stage F-stat				
Dictator game	52.35***	52.35***	19.84***	19.84***
Trust game			23.47***	23.47***
Observations	163	163	163	163
R-squared	0.539	0.494	0.493	0.400

Note: Clustered standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Source: Author's calculations.

4.5 Cropping pattern

Another possible concern is that the cropping pattern might differ among canal sections depending on their water accessibility (e.g. Ray and Williams, 2002). It is possible that upstream farmers with adequate water access might cultivate paddy whereas downstream farmers with lower water access might cultivate less-water-intensive crops. In this case, the previous empirical results might be biased. Table 7 shows the cropping pattern calculated

Table 6. Effect of altruism and trust on satisfaction level of water usage with paddy yield

	(1)	(2)	(3)	(4)
	IV	IV	IV	IV
Type of social capital	Altruism	Altruism	Trust	Trust
Dependent variable	Binary	%	Binary	%
Dictator game	0.024	9.905	−0.569	−0.132
	(0.265)	(10.917)	(0.576)	(20.830)
Vs_downstream × dictator game	0.074	6.485		
	(0.128)	(4.875)		
Vs_upstream × dictator game	−0.270	−9.561		
	(0.167)	(6.846)		
Trust game			0.716	15.677
			(0.526)	(18.449)
Vs_downstream × trust game			0.223*	10.492**
			(0.120)	(4.361)
Vs_upstream × trust game			−0.215	−5.536
			(0.153)	(5.343)
Dice game			−0.245	−14.235**
			(0.165)	(6.313)
Log (yield)	0.048	3.364*	0.056	3.682*
	(0.049)	(1.822)	(0.051)	(1.882)
Middle	−0.060	0.239	0.003	2.857
	(0.082)	(2.969)	(0.095)	(3.270)
Tail	−0.116	1.719	−0.056	3.598
	(0.101)	(3.607)	(0.110)	(3.890)
Log (plot size)	−0.048	−2.892	−0.118	−4.797
	(0.103)	(4.078)	(0.122)	(4.477)
Household head	0.080	1.004	0.115	1.935
	(0.087)	(2.991)	(0.088)	(3.070)
Age of household head	0.000	0.013	0.001	0.083
	(0.005)	(0.171)	(0.005)	(0.176)
Female household head	0.108	1.123	0.001	−3.131
	(0.120)	(5.233)	(0.127)	(5.684)
Education of household head	0.022**	0.684	0.027**	0.748*
	(0.010)	(0.419)	(0.012)	(0.450)
Re-settler	−0.013	0.542	0.010	1.339
	(0.065)	(2.423)	(0.067)	(2.437)
Number of members in non-agriculture	0.015	1.247	0.011	1.113
	(0.018)	(0.821)	(0.019)	(0.811)
Years of access to D-canal	−0.011**	−0.269	−0.012*	−0.241
	(0.005)	(0.225)	(0.006)	(0.238)
Years of Experience in Farming	0.001	0.077	−0.001	−0.018
	(0.004)	(0.145)	(0.004)	(0.152)
D-canal dummies	YES	YES	YES	YES
First stage F-stat				
Dictator game	16.66***	16.66***	24.83***	24.83***
Vs_downstream × dictator game	38.35***	38.35***		
Vs_upstream × dictator game	26.63***	26.63***		

(continued)

Table 6. Continued

	(1)	(2)	(3)	(4)
	IV	IV	IV	IV
Type of social capital	Altruism	Altruism	Trust	Trust
Dependent variable	Binary	%	Binary	%
Trust game			68.19***	68.19***
Vs_downstream × trust game			50.19***	50.19***
Vs_upstream × trust game			24.83***	24.83***
Observations	523	523	523	523
R-squared	0.423	0.428	0.359	0.405

Note: Clustered standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Source: Author's calculations.

Table 7. Cropping pattern by canal section

	Mean			*t*-value
	Head	Middle	Tail	(head vs tail)
Sample size	50	81	58	
Share of paddy cultivated land	0.728	0.721	0.765	−0.633

Source: Author's calculations.

as the share of paddy-cultivated land out of total cultivated land in the head, middle, and tail areas. The table reveals that there is little difference among canal sections. Therefore, these results are free from bias arising from possible systematic differences in cropping patterns.

4.6 Reciprocal behavior of downstream farmers

The finding that only trust toward downstream farmers has a significantly positive impact implies that the trust motive fits better than the self-interested or altruistic motives. Thus, it is important to confirm that there are reciprocal behaviours from downstream farmers which induce higher cooperation from upstream farmers. As mentioned above, reciprocal behaviour can take the form of downstream farmers cooperating in irrigation canal management (Ostrom and Gardner, 1993; Jack, 2009) or some other form of social exchange[22] (Aoki, 2001).

In the study site, farmers have to clean not only the canal around their plots but also upstream dams, which is beneficial for upstream farmers as well as downstream farmers. This type of irrigation management increases the water flow in the whole canal, which is comparable to the type of cooperation studied in classical survey-based studies

22 In order to explain cooperation in irrigation management, Aoki (2001) developed the linked game model where players play both irrigation maintenance game and social exchange game. In this model, players cooperate in irrigation management even though they have an incentive to shirk, out of fear of being ostracized from social exchanges such as mutual aid and social events.

(e.g. Ostrom and Gardner, 1993) as well as recent experimental studies (e.g. Cardenas *et al.*, 2013). In fact, almost all households in the data set participated in cleaning the irrigation canals. This situation can be interpreted as downstream farmers' reciprocal behaviour.

More evidence can be found in the risk sharing arrangement, which is an important domain of social exchange in rural communities. In a risk sharing group formation, geographical distance increases the merit of diversifying risks, while it also raises the transaction cost of establishing and implementing the risk sharing (e.g. Murgai *et al.*, 2002; Fafchamps and Gubert, 2007). In our setting, the transaction costs are expected to be very low because the farmers are embedded in the same irrigation canal, and the upstream farmers have an incentive to form a group with downstream farmers. In this situation, upstream farmers also have an incentive to leave more water for downstream farmers so that they can expect cooperation in the risk sharing domain.

In order to test this hypothesis, we analyse whether the locational variations within a D-canal have some effects on risk sharing group formation. In the study site, there is a microcredit scheme with joint liability, which can be regarded as a form of risk sharing (Fafchamps, 2011). To test the determinants of the formation of this microfinance group, the following dyadic regression model (Fafchamps and Gubert, 2007) is estimated:

$$y_{ij} = \beta vs\_other_{ij} + \gamma_1 |x_i - x_j| + \gamma_2 (x_i + x_j) + \epsilon_{ij}$$

where y_{ij} denotes whether i and j are in the same microcredit group, vs_other_{ij} denotes whether i and j are in a different location within a canal, i.e. $(i, j) \in \{(head, middle), (head, tail), (middle, head), (middle, tail), (tail, head), (tail, middle)\}$, and x_i and x_j denote the observed characteristics of i and j, respectively. The parameter of interest is β, which indicates that farmers tend to form a group with a partner in a different location so that it maximizes the benefit of diversifying risks. Note that standard errors are clustered at experimental session level (Attanasio *et al.*, 2012).

Table 8 shows the estimation results of the dyadic regression model. A farmer tends to form a group with those who are in a different section within a canal. This kind of connection outside irrigation management provides the upstream farmers with an incentive to leave water for the downstream farmers in the expectation of reciprocal behaviour in risk sharing or for fear of losing cooperation in the risk sharing domain, which is comparable to the situation modelled by Aoki (2001).[23]

5. Conclusion

Social capital has long been considered a key instrument in CPR management, but little consensus has emerged regarding its effect on the water allocation problem between upstream and downstream farmers along an irrigation canal. Existing studies have analysed observational or experimental data only, and the effect of social capital on actual CPR management among heterogeneous players remains an important yet hitherto unaddressed issue. This study bridges the gap by combining a lab-in-the-field experiment and household survey data. Additionally, the natural experimental situation of the study site enables us to overcome potential differences in income or asset holdings between head-enders and tail-enders. Thus, this study clearly estimates the effect of social capital on farmers' satisfaction with irrigation water provision.

23 Chi-square tests also confirm that the formation of lending groups are not independent from whether they are in a different position within a canal at 10% significance level.

Table 8. Determinants of risk sharing group formation

Dependent variable	(1) Same group	(2) Same group
Partner is in a different canal section	0.065*	0.070*
	(0.037)	(0.038)
Difference in:		
Log (plot size)	0.004	0.053
	(0.014)	(0.052)
Household head	0.102**	0.058
	(0.051)	(0.054)
Age of household head	0.001	0.001
	(0.002)	(0.002)
Female household head	−0.086**	−0.082
	(0.041)	(0.053)
Education of household head	0.006	0.007
	(0.007)	(0.007)
Re-settler	−0.037	−0.051*
	(0.025)	(0.025)
Number of members in non-agriculture	−0.019*	−0.010
	(0.010)	(0.010)
Years of access to D-canal	−0.001	−0.002
	(0.002)	(0.002)
Years of Experience in Farming	0.001	0.001
	(0.002)	(0.002)
Sum of the characteristics	NO	YES
D-canal dummies	YES	YES
Observations	477	477
R-squared	0.211	0.260

Note: Clustered standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Source: Author's calculations.

The most important finding is that social capital with respect to downstream famers, especially trust toward them, has a significantly positive effect on satisfaction with water usage. This is consistent with the hypothesis that upstream farmers with higher trust use less irrigation water, thus caring for downstream farmers. Another finding is that OLS estimators for these social capital variables are downward biased, which is consistent with the hypothesis that scarcity of resources induces social capital accumulation.

The result that trust, rather than altruism, plays an important role in irrigation water demand implies that upstream farmers expect positive reciprocity from downstream farmers. Consistent with the previous studies, this study also finds that downstream farmers can contribute to maintenance of irrigation canal and risk sharing as a form of social exchange, which in turn provides the upstream farmers with an incentive to leave more water for them.

In addition to these main findings, the significantly positive effects found in the dictator and trust games provide a unique case study of the real-world relevance of standard experiments that attempt to measure social capital. By considering the irrigation water allocation problem for upstream farmers as a natural dictator or trust game, the results show a strong link between lab-in-the-field experiments and actual economic transactions.

Finally, a unique aspect of the study site should be reiterated. Because the study site is a newly settled area, locational advantages and disadvantages are free from heterogeneities in income and wealth. Additionally, there is limited heterogeneity in ethnicity in this area. As for irrigation, water allocation across D-canals is controlled by the authorities, and a relatively small number of farmers engage in the management of D-canals. As such, the level of social capital is easily enhanced within a D-canal through collective management (Aoyagi *et al.*, 2014). Thus, to fully utilize the effect of social capital in irrigation management, as explored in this study, it is important for policymakers to foster conditions that enhance social capital rather than simply de-centralizing the entire irrigation management to local farmers.

Supplementary material

Supplementary material is available on the OUP website. The data are the property of JICA Research Institute and are confidential. The supplementary material comprises the replication files and the Online Appendix.

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References

Agrawal, A. (2001) Common property institutions and sustainable governance of resources, *World Development*, **29**, 1649–72.

Aoki, M. (2001) Community norms and embeddedness: a game-theoretic approach, in M. Aoki and Y. Hayami (eds) *Communities and Markets in Economic Development*, Oxford University Press, Oxford, 97–125.

Aoki, M. and Hayami, Y. (eds) (2001) *Communities and Markets in Economic Development*, Oxford University Press, Oxford.

Aoyagi, K., Sawada, Y., and Shoji, M. (2014) Does infrastructure facilitate social capital accumulation? Evidence from natural and artefactual field experiments in Sri Lanka. JICA-RI Working Paper, No. 65, JICA Research Institute, Tokyo.

Attanasio, O., Barr, A., Cardenas, J.C., Genicot, G., and Meghir, C. (2012) Risk pooling, risk preferences, and social networks, *American Economic Journal of Applied Economics*, **4**, 134–67.

Baland, J.-M. and Platteau, J.P. (2000) *Halting Degradation of Natural Resources: Is There a Role for Rural Communities*? Oxford University Press, Oxford.

Bardhan, P. (2000) Irrigation and cooperation: an empirical analysis of 48 irrigation communities in South India, *Economic Development and Cultural Change*, **48**, 847–65.

Bardhan, P. and Dayton-Johnson, J. (2002) Unequal irrigators: heterogeneity and commons management in large-scale multivariate research, in **National Research Council** (ed.) *The Drama of the Commons*, National Academy Press, Washington, DC, 87–112.

Barr, A. and Serneels, P. (2008) Reciprocity in the workplace, *Experimental Economics*, **12**, 99–112.

Basu, D. (2015) Asymptotic bias of OLS in the presence of reverse causality. Economics Department Working Paper Series, 179, University of Massachusetts, Amherst, MA.

Becker, G.S. (1974) A theory of social interactions, *Journal of Political Economy*, **82**, 1063–93.

Berg, J., Dickhaut, J., and McCabe, K. (1995) Trust, reciprocity, and social history, *Games and Economic Behavior*, **10**, 122–42.

Bignon, V., Caroli, E., and Galbiati, R. (2017) Stealing to survive? Crime and income shocks in nineteenth century France, *The Economic Journal*, **127**, 19–49.

Bouma, J., Bulte, E., and van Soest, D. (2008) Trust and cooperation: social capital and community resource management, *Journal of Environmental Economics and Management*, **56**, 155–66.

Bowles, S. and Gintis, H. (2002) Social capital and community governance, *The Economic Journal*, **112**, F419–36.

Brandts, J. and Charness, G. (2011) The strategy versus the direct-response method: a first survey of experimental comparisons, *Experimental Economics*, **14**, 375–98.

Burks, S.V., Carpenter, J.P., and Verhoogen, E. (2003) Playing both roles in the trust game, *Journal of Economic Behavior & Organization*, **51**, 195–216.

Camerer, C.F. and Fehr, E. (2004) Measuring social norms and preferences using experimental games: a guide for social scientists, in J. Henrich, R. Boyd, S. Bowles, C.F. Camerer, E. Fehr, and H. Gintis (eds) *Foundations of Human Sociality: Economic Experiments and Ethnographic Evidence from Fifteen Small-Scale Societies*, Oxford University Press, Oxford, 55–95.

Cardenas, J.C. (2011) Social norms and behavior in the local commons as seen through the lens of field experiments, *Environmental and Resource Economics*, **48**, 451–85.

Cardenas, J.C. and Carpenter, J. (2008) Behavioral development economics: lessons from field labs in the developing world, *Journal of Development Studies*, **44**, 311–38.

Cardenas, J.C., Rodriguez, L.A., and Johnson, N. (2010) Collective action for watershed management: field experiments in Colombia and Kenya, *Environment and Development Economics*, **16**, 275–303.

Cardenas, J.C., Janssen, M., and Bousquet, F. (2013) Dynamics of rules and resources: three new field experiments on water, forests and fisheries, in J. List and M. Price (eds) *Handbook on Experimental Economics and the Environment*, Edward Elgar Publishing, Northampton, MA, 319–45.

Carpenter, J. and Seki, E. (2011) Do social preferences increase productivity? Field experimental evidence from fishermen in Toyama Bay, *Economic Inquiry*, **49**, 612–30.

Carter, M.R. and Castillo, M. (2011) Trustworthiness and social capital in South Africa: analysis of actual living standards data and artefactual field experiments, *Economic Development and Cultural Change*, **59**, 695–722.

Chakravorty, U. and Roumasset, J. (1991) Efficient spatial allocation of irrigation water, *American Journal of Agricultural Economics*, **73**, 165–73.

Coleman, J.S. (1988) Social capital in the creation of human capital, *American Journal of Sociology*, **94**, S95–120.

Cox, J.C. (2004) How to identify trust and reciprocity, *Games and Economic Behavior*, **46**, 260–81.

D'Exelle, B., Lecoutere, E., and Van Campenhout, B. (2012) Equity-efficiency trade-offs in irrigation water sharing: evidence from a field lab in rural tanzania, *World Development*, **40**, 2537–51.

Durlauf, S.N. and Fafchamps, M. (2005) Social capital, in P. Aghion and S.N. Durlauf (eds) *Handbook of Economic Growth*, North Holland, Amsterdam, 1639–99.

Etang, A., Fielding, D., and Knowles, S. (2011) Does trust extend beyond the village? Experimental trust and social distance in Cameroon, *Experimental Economics*, **14**, 15–35.

Fafchamps, M. (2011) Risk sharing between households, in J. Benhabib, A. Bisin, and M. Jackson (eds) *Handbook of Social Economics*, North Holland, Amsterdam, 1255–80.

Fafchamps, M. and Gubert, F. (2007) The formation of risk sharing networks, *Journal of Development Economics*, **83**, 326–50.

Fehr, E. and Leibbrandt, A. (2011) A field study on cooperativeness and impatience in the tragedy of the commons, *Journal of Public Economics*, **95**, 1144–55.

Ferguson, C.A. (1992) Water allocation, inefficiency and inequity in a government irrigation system, *Journal of Development Economics*, **38**, 165–82.

Forsythe, R., Horowitz, J.L., Savin, N.E., and Sefton, M. (1994) Fairness in simple bargaining games, *Games and Economic Behavior*, **6**, 347–69.

Fujiie, M., Hayami, Y., and Kikuchi, M. (2005) The conditions of collective action for local commons management: the case of irrigation in the Philippines, *Agricultural Economics*, **33**, 179–89.

Gneezy, U. and Imas, A. (2017) Lab in the field: measuring preferences in the wild, in A.V. Banerjee and E. Duflo (eds) *Handbook of Economic Field Experiments*, **vol. 1**, North Holland, Amsterdam, 439–64.

Hardin, G. (1968) The tragedy of the commons, *Science*, **162**, 1243–8.

Hayami, Y. (2009) Social capital, human capital and the community mechanism: toward a conceptual framework for economists, *Journal of Development Studies*, **45**, 96–123.

Hoffman, E., McCabe, K., and Smith, V.L. (1996) Social distance and other-regarding behavior in dictator games, *American Economic Review*, **86**, 653–60.

Holt, C.A., Johnson, C.A., Mallow, C.A., and Sullivan, S.P. (2012) Water externalities: tragedy of the common canal, *Southern Economic Journal*, **78**, 1142–62.

Jack, B.K. (2009) Upstream-downstream transactions and watershed externalities: experimental evidence from Kenya, *Ecological Economics*, **68**, 1813–24.

Janssen, M.A., Anderies, J.M., and Cardenas, J.-C. (2011) Head-enders as stationary bandits in asymmetric commons: comparing irrigation experiments in the laboratory and the field, *Ecological Economics*, **70**, 1590–8.

JBIC Institute. (2007) Impact of irrigation infrastructure development on dynamics of incomes and poverty: econometric evidence using panels data from Sri Lanka. JBICI Research Paper No. 32, JBIC Institute, Tokyo.

Kajisa, K., Palanisami, K., and Sakurai, T. (2007) Effects on poverty and equity of the decline in collective tank irrigation management in Tamil Nadu, India, *Agricultural Economics*, **36**, 347–62.

Karlan, D.S. (2005) Using experimental economics to measure social capital and predict financial decisions, *American Economic Review*, **95**, 1688–99.

Kosfeld, M. and Rustagi, D. (2015) Leader punishment and cooperation in groups: experimental field evidence from commons management in Ethiopia, *American Economic Review*, **105**, 747–83.

Leider, S., Möbius, M.M., Rosenblat, T., and Do, Q.-A. (2009) Directed altruism and enforced reciprocity in social networks, *Quarterly Journal of Economics*, **124**, 1815–51.

Levitt, S.D. and List, J.A. (2007) What do laboratory experiments measuring social preferences reveal about the real world? *Journal of Economic Perspectives*, **21**, 153–74.

Mehlum, H., Miguel, E., and Torvik, R. (2006) Poverty and crime in 19th century Germany, *Journal of Urban Economics*, **59**, 370–88.

Meinzen–Dick, R., Raju, K.V., and Gulati, A. (2002) What affects organization and collective action for managing resources? Evidence from canal irrigation system in India, *World Development*, **30**, 649–66.

Miguel, E. (2005) Poverty and witch killing, *The Review of Economic Studies*, **72**, 1153–72.

Miguel, E., Satyanath, S., and Sergenti, E. (2004) Economic shocks and civil conflict: an instrumental variables approach, *Journal of Political Economy*, **112**, 725–53.

Murgai, R., Winters, P., Sadoulet, E., and de Janvry, A. (2002) Localized and incomplete mutual insurance, *Journal of Development Economics*, **67**, 245–74.

Nakano, Y. and Otsuka, K. (2011) Determinants of household contributions to collective irrigation management: the case of the doho rice scheme in Uganda, *Environment and Development Economics*, **16**, 527–51.

Ostrom, E. (1990) *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, New York.

Ostrom, E. (1999) Social capital: a fad or a fundamental concept? in P. Dasgupta and I. Serageldin (eds), *Social Capital: A Multifaceted Perspective*, World Bank, Washington, DC, 172–214.

Ostrom, E. (2006) The value-added of laboratory experiments for the study of institutions and common-pool resources, *Journal of Economic Behavior & Organization*, **61**, 149–63.

Ostrom, E. (2009) A general framework for analyzing sustainability of social-ecological systems, *Science*, **325**, 419–22.

Ostrom, E. and Gardner, R. (1993) Coping with asymmetries in the commons: self-governing irrigation systems can work, *Journal of Economic Perspectives*, **7**, 93–112.

Pfaff, A., Vélez, M.A., Ramos, P.A., and Molina, A. (2015) Framed field experiment on resource scarcity & extraction: path-dependent generosity within sequential water appropriation, *Ecological Economics*, **120**, 416–29.

Putnam, R.D. (1993) *Making Democracy Work: Civic Traditions in Modern Italy*, Princeton University Press, Princeton, NJ.

Ray, I. and Williams, J. (2002) Locational asymmetry and the potential for cooperation on a canal, *Journal of Development Economics*, **67**, 129–55.

Roe, B.E. and Just, D.R. (2009) Internal and external validity in economics research: tradeoffs between experiments, field experiments, natural experiments, and field data, *American Journal of Agricultural Economics*, **91**, 1266–71.

Schechter, L. (2007) Traditional trust measurement and the risk confound: an experiment in rural Paraguay, *Journal of Economic Behavior & Organization*, **62**, 272–92.

Schoengold, K. and Zilberman, D. (2006) The economics of water, irrigation, and development, in R. Evenson and P. Pingali (eds) *Handbook of Agricultural Economics*, North Holland, Amsterdam, 2933–77.

Sellamuttu, S.S., Aida, T., Kasahara, R., Sawada, Y., and Wijerathna, D. (2014) How access to irrigation influences poverty and livelihoods: a case study from Sri Lanka, *Journal of Development Studies*, **50**, 748–68.

Tajfel, H., Billig, M.G., Bundy, R.P., and Flament, C. (1971) Social categorization and intergroup behavior, *European Journal of Social Psychology*, **1**, 149–77.

Tang, S.Y. (1992) *Institutions and Collective Action: Self-Governance in Irrigation*, Institute for Contemporary Studies, San Francisco, CA.

Velez, M.A., Stranlund, J.K., and Murphy, J.J. (2009) What motivates common pool resource users? Experimental evidence from the field, *Journal of Economic Behavior & Organization*, **70**, 485–97.

Wade, R. (1988) *Village Republics: Economic Conditions for Collective Action in South India*, Cambridge University Press, Cambridge.