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Social Capital as an Instrument for Common Pool Resource Management: A Case Study of Irrigation Management in Sri Lanka

Takeshi Aida*

Abstract

This paper investigates the effect of social capital between irrigation canal head-enders and tail-enders on their water allocation problem. Although social capital is considered to be an instrument for common pool resource management, a consensus has not been reached on its effect among heterogeneous players. In irrigation management, the water allocation problem between head-enders and tail-enders is one of these serious problems. Using unique natural and artefactual field experiment data as well as general household survey data collected by JICA, this study finds that social capital, especially trust toward their tail-enders, has a significantly positive effect on satisfaction with water usage among head-enders. Considering the fact that the incentive structure of irrigation water allocation for head-enders closely resembles that in the dictator and trust games, this finding also supports the validity of experimentally measured social capital. In addition, this study deals with the simultaneity bias between satisfaction level and experimentally measured social capital, and finds that OLS estimators are downward biased, which is consistent with the hypothesis that scarcity of resources enhances the level of social capital.

Keywords: social capital; irrigation; field experiment; head-enders and tail-enders

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1. Introduction

Common pool resources (CPRs) are characterized by non-excludability and rivalness of consumption. These characteristics lead rational players to use these resources more than the socially optimal level, and ultimately they will be exhausted. This is the well-known story of the "tragedy of the commons" (Hardin 1968). However, many empirical studies have shown that this tragedy does not occur even in developing countries where formal institutions are weak (e.g., Ostrom 1990; Aoki and Hayami 2001). The key instrument for the success of CPR management is social capital[1] (Hayami 2009).

In the theoretical background, CPR management is often explained by a repeated game (e.g., Baland and Platteau 2000), but these models do not explicitly include social capital. One interesting exception is the linked game model in Aoki (2001). In this model, players play an irrigation maintenance game and a social exchange game simultaneously. As it is impossible to restrict irrigation access, players have an incentive to shirk in the irrigation maintenance game. However, other players can punish selfish players by excluding them from the social exchange game, and thus if the return from social exchange is large enough, players will cooperate in maintenance and the irrigation system will be well-maintained. The existence of social capital thus prevents selfish behavior and leads to better resource management.

Although social capital seems to be an effective instrument, there are some situations in which it cannot work properly. Bardhan and Dayton-Johnson (2002) survey various empirical studies and conclude that irrigation management is difficult when there is heterogeneity among the players. They identify several types of heterogeneities: income or wealth inequality, asymmetry between head-enders and tail-enders, exit options, and ethnic or social heterogeneity. Among these, the specific problem for irrigation management is the

1. There are various definitions of social capital (e.g., Durlauf and Fafchamps 2005). Based on Hayami (2009), this paper defines it as informal mechanisms based on norms and trust that induce cooperation among members. Among these, this study especially focuses on altruism and trust within the CPR user group.

head-enders and tail-enders problem. These two groups differ in terms of their access to irrigation water: if head-enders use too much water first, tail-enders cannot use enough. This type of heterogeneity leads to the failure of irrigation management.

The effect of the head and tail asymmetry problem in irrigation water management is ambiguous. Wade (1988) points out that water shortage involves an inherent conflict between upstream and downstream farmers. Tang (1992) finds that the presence of a disadvantaged group, which refers to tail-enders in most cases, leads to the failure of rule conformance and maintenance. Though Ostrom and Gardner (1993) find that irrigation maintenance between head-enders and tail-enders can be achieved, they also find that such collective actions are difficult when there is a large difference in water availability between them. Fujiie et al. (2005) also find that a difference in water availability negatively affects irrigation maintenance. However, these survey-based analyses cannot directly identify the effect of social capital on the collective action problem. In addition, these studies focus on irrigation maintenance, not on the water allocation problem.

In addition to these analyses, there is a growing literature on CPR experiments (Ostrom 2006; Cardenas 2011). Among these, one of the most relevant experiments for this study is the irrigation game introduced by Cardenas et al. (2008): they find that the head and tail problem diminishes after an extraction rule is enforced. Holt et al. (2010) show that chatting among players leads to more efficient water allocation, although it is less efficient than market mechanisms, such as Pigouvian taxes or auctions. Cardenas et al. (2011) also show that face-to-face communication can achieve better cooperation among players. However, the outcome in these experiments is not an actual allocation of irrigation water, and canal locations do not reflect actual locations. Thus the external validity of these games is still an important issue to be addressed.

This study aims to bridge these limitations in both survey-based and experimental analyses by showing the link between actual irrigation water allocation and experimentally measured social capital. In order to incorporate social capital into an empirical model, it is necessary to measure the level of social capital. Recent developments in experimental methods have enabled us to measure social capital quantitatively (Camerer and Fehr 2004; Cardenas and Carpenter 2008; Levitt and List 2007). Furthermore, social capital measured by these experimental methods can predict actual economic outcomes, such as the repayment rate in microfinance (Karlan 2005), household per-capita expenditure (Carter and Castillo 2009), workers' productivity in the workplace (Barr and Serneels 2008), and irrigation maintenance (Bouma et al. 2008[2]).

The main contribution of this paper is to estimate the effect of social capital between head-enders and tail-enders on the irrigation water allocation problem. This paper uses a unique dataset of an irrigation project in southern Sri Lanka, which was collected by Japan International Cooperation Agency (JICA). It contains artefactual field experiment data from a dictator game and a trust game, as well as household survey data. In addition, the study site has a unique natural experimental setting in which the distribution of irrigated plots was exogeneously determined. Making use of these advantages, this paper can estimate the effect of social capital on irrigation water allocation in an ideal setting.

Another contribution of this paper is to show the validity of experimentally measured social capital. There have been criticisms of using experimental methods to measure social capital because the results of experiments are affected by many factors (Levitt and List 2007). However, this paper can demonstrate links between the results of experiments and actual economic transactions, because the incentive structure of irrigation water allocation for head-enders closely resembles those in the dictator and trust games. In actual irrigation water allocation, it is difficult to charge water extraction fees according to the usage amount (Schoengold and Zilberman 2006). Because of this feature, rational farmers' optimal strategy is

2. Bouma et al. (2008) is the first study to investigate the effect of social capital on irrigation management using a trust game. However, they do not show its effect on water allocation among heterogeneous players.

to extract as much water as they want, which means that tail-enders may not be able to use enough water. In the dictator and trust games, the proposer is endowed with a certain amount of money, and he/she decides how much to send to the partner. The optimal strategy for the proposer in these games is to send nothing and keep all the money. In the trust game, receivers have the option to send back to the proposer, which is the equivalent of tail-enders cooperating in irrigation canal management. By comparing the "natural" dictator or trust games to the artefactual field experiment results, this paper can show the validity of these games in a more desirable setting.

This paper is organized as follows. Section 2 describes the study site and its natural experimental situation as well as the artefactual field experiment data. Section 3 describes the empirical strategy this paper exploits. Section 4 shows descriptive statistics and looks into the main empirical results. The final section offers a summary and concluding remarks.

2. Data

2.1 Study site and natural experimental situation

This paper uses a dataset from an irrigation project in Sri Lanka, which was originally collected by JICA.[3] The study site is Walawe Left Bank (WLB), located in the southern part of Sri Lanka. The government of Sri Lanka constructed the Uda Walawe reservoir during the period 1963-1967. This reservoir is located on the boundary between the wet and dry zones of Sri Lanka and the rainfall pattern in this area is influenced by monsoon winds. There are two main canals in this basin: the Right Bank Main Canal (RBMC) and the Left Bank Main Canal (LBMC). Construction of the RBMC was completed with the financial assistance of the Asian Development Bank (ADB) under the Walawe Development Project (1969-1977) and the Walawe Irrigation Improvement Project (1986-1994). Construction of the LBMC, which is the focus of this paper, was launched in 1997 with Japanese ODA loans. By the end of 2008,

3. See JBIC Institute (2007) for details.

almost every household had acquired access to irrigation facilities.

The study site is divided into five blocks, according to their accessibility to irrigation: Sevanagala Irrigated, Sevanagala Rainfed,[4] Kiriibbanwewa, Sooriyawewa, and Extension Area. In each block, there are a number of distribution canals (D-canals) that draw water from the main canal in order to distribute it to each area of farmland. Figure 1 shows the sampling structure of the original dataset and the relationship between each block and the D-canals. The water supply is controlled at the level of each D-canal by the authorities, and thus collective action to manage irrigation water is conducted at the level of each D-canal.

The study site possesses unique natural experimental characteristics that are ideal for this study. As Bardhan and Dayton-Johnson (2002) mention, locational advantages and disadvantages, such as the head or tail relative to the irrigation canal, will be reflected in land values if land markets work reasonably well. However, the study site is free from this problem because the distribution of the irrigated plots was determined partly by a lottery mechanism.[5] In addition, property rights to the irrigated plots were not given to the farmers until April 2009, and therefore farmers could neither sell nor collateralize their irrigated plots until that time.

Figures 2 and 3 show the cumulative distribution functions (CDFs) of income and total irrigated plot size by canal section. These graphs show that there is no systematic difference in income or irrigated land size among three different locations along the canals: the head, middle, and tail. In addition, the Kolmogorov-Smirnov test cannot reject the null hypothesis at the 10% level that two distributions are generated by the same underlying distribution for all pairs (i.e., head and middle, head and tail, middle and tail) in terms of both income and total irrigated plot size. These results suggest that the data are free from systematic differences in income or plot size between head-end and tail-end, and therefore this study can address head and tail

4. There is no irrigation access in Sevanagala Rainfed area because of topographic constraints. This study excludes people living in this area.
5. Unfortunately, only about 30% of households answered that their plots were determined by the lottery. However, there is no systematic difference within D-canals after controlling for block fixed effects (Aoyagi et al. 2010).

asymmetry with cleaner data compared to previous studies.

Another important feature is that all of the samples are Sinhala speakers and belong to the same religious group. Although ethnic conflict between Sinhala and Tamil has been a serious problem in Sri Lanka, it is not necessary to consider this problem in the study site, and so the dataset is free from ethnic and social heterogeneity, which is also suggested as a type of heterogeneity in Bardhan and Dayton-Johnson (2002).

2.2 Artefactual field experiment

JICA (formerly JBIC) initiated a household survey in 2001 to assess the impact of the irrigation system. They had conducted eight household surveys by May 2009 and conducted one field experimental session in March 2009.

The experiments comprised the dictator game, trust game, and risk game. The sample was 268 farmers randomly selected from the survey area. Figure 1 shows the sampling structure by each block and D-canal level. Of the 268 samples, 188 were included in the previous household survey and 80 were not. Although the participants originally invited were household heads or members of a household, seven households could not sent household members to the experiment; instead, they sent a son or daughter living separately in another city. Because these agent players are irrelevant from the perspective of actual irrigation management, they are excluded from this study.

The experiments exploited the strategy method. In the dictator and trust games, each player was given Rs. 500, which was equivalent to one day's wages for a typical farmer in the study area, and they decided on an amount $x \in \{0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500\}$ to send to four types of partners: three non-anonymous people 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.

In the dictator game, players decided how much to send to their partners, and the partners received the same amount as what the player sent. In the trust game, when all the participants finished their decision-making as senders, they were paired with one of the other participants from the same D-canal. However, they were informed that they would be paired randomly with one of all potential receivers with whom they were playing the game, but that they could not identify their partners. The amount transferred was based on their strategy as senders and tripled when their partners received. All participants, when they were receivers, knew only the tripled amount they had received from their partner, and decided how much to send back to their four potential partners. Note that all the participants were paired with only one of three potential partners. In other words, they decided on their amount to send back to four types of partners, as though the amount they received had been from each of them.[6]

In both games, the players would not send any money in a Nash equilibrium, and thus deviation from the Nash equilibrium is interpreted as altruism in the dictator game and trust in the trust game (e.g., Camerer and Fehr 2004; Levitt and List 2007). Note that the incentive structures in these games are similar to those faced by a head-ender in an actual irrigation water allocation problem.

In addition to these games, a dice game was conducted in order to measure their risk attitude. A player was given Rs. 500 as an initial endowment and the option of how much, if any, to invest. The player then rolled a die with different colors on each of the six faces to determine the investor's payoffs, which is based on Schechter (2007). Table 1 shows the payoff for each color. The amount invested in this game represents the player's risk attitude.

3. Empirical strategy

Using the experimentally measured social capital variable, this paper aims to estimate its effect on the water allocation problem. In the case of pure self-interest, head-end farmers

6. Because of this feature, the amount sent back might not capture true trustworthiness. For this reason, this study does not investigate the effect of receivers' behavior in the trust game.

have an incentive to extract more water than the socially optimal level, because it is impossible to charge extraction fees according to their usage amount. However, farmers with higher social capital optimize their water demand so as to care for tail-enders, and thus their water demand level should be lower than that of farmers with lower social capital.

This study focuses on farmers who cultivate paddy fields (rice) in the irrigated land, for two reasons. First, paddy-grown rice is the major crop in this area and is cultivated by 78% of the sample. Second, paddies require much more water during the growing season compared to other crops. The water allocation problem is thus most serious in paddy cultivation.

One of the hurdles to be overcome is to measure water allocation at the level of each individual. As Schoengold and Zilberman (2006) mention, it is hard to measure individual water usage directly. Instead, this study uses subjective answers to question asking about farmers' satisfaction with water usage during Maha, which is the rainy season, from October to March, 2008-2009. The variables comprise a discrete variable that represents whether or not they were satisfied, and, if they were not satisfied, a continuous variable that shows the percentage of water they used compared to the amount they wanted.[7] The Appendix discusses the validity of using these subjective answers.

Regarding land holdings, some farmers had more than one irrigated plot. Although the dataset contains water satisfaction levels for each plot, it is impossible to identify what crop they were cultivating at each plot. This study primarily focuses on the main plot, which is defined as the largest irrigated plot possessed by each household. In addition to these variables, the averages of satisfaction for each plot weighted by plot size are used as alternative measures. These alternative measures are calculated as follows:

7. The percentage satisfaction variable is given as 100 if they answered that they were satisfied with their water usage.

$$average\_satisfaction_i = \frac{\sum_p size_{ip} \cdot satisfaction_{ip}}{\sum_p size_{ip}}, \tag{1}$$

where $size_{ip}$ is the size of household i's irrigated plot p, and $satisfaction_{ip}$ represents the satisfaction variables for plot p.

It is natural to assume that satisfaction with water usage is determined by the difference between demand and supply: if demand for irrigation water exceeds the level of supply, a farmer will not be satisfied. Thus, if the water supply level is controlled, farmers with a larger water demand would tend to be less satisfied with their water usage. According to the hypothesis, farmers with higher social capital would refrain from selfish behavior and their water demand would be smaller, and thus stronger social capital would lead to a higher level of satisfaction. In order to control for the water supply level, D-canal fixed effects are included. These fixed effects capture all the differences within the CPR user group, including the water supply level.[8]

As noted above, head-enders and tail-enders face different water usage incentive structures. Head-enders with higher social capital will decide how much water to use while considering tail-enders. In contrast, tail-enders do not need to consider head-enders, because they are the last people to extract water. Therefore, although social capital is expected to have a significantly positive effect on satisfaction for head-enders, its effect for tail-enders is unclear. This structure closely resembles that of the dictator game and trust game, where the first mover decides how much of a resource they will keep and how much they will send to their partner. In order to take this asymmetry into account, the game results distinguish between whether the partner is at the head or the tail relative to the player.

8. Because irrigation management is conducted at the D-canal level, the extraction rules and punishments for violators may differ among D-canal areas. There is no data on these rules, but the D-canal fixed effects also control for these systematic differences.

Because the dataset contains game results for three partners per player in the dictator game and trust game, the respective data are stacked for each observation. In each observation, players can identify whether their partner's plot is located in a head/tail area relative to themselves. Because samples were selected randomly from each D-canal, cross terms of the game results and whether the partner's plot is in a head/tail area capture the mean level of altruism and trust toward the head/tail-enders. The specification is as follows:

$$satisfaction_i = \alpha + \beta_1 SC_{ij} + \beta_2 vs\_tail_{ij} \cdot SC_{ij} + \beta_3 vs\_head_{ij} \cdot SC_{ij} + X_i \gamma + DC_i + \varepsilon_{ij} \quad (2)$$

where SC_{ij} is the amount sent from player i to partner j in the dictator or trust game, and vs_tail_{ij} and vs_head_{ij} are binary variables that take one if j has a plot in the tail-end or head-end relative to i, i.e., $vs\_tail_{ij} = 1$ if $(i, j) \in \{(head, middle), (head, tail), (middle, tail)\}$ and $vs\_head_{ij} = 1$ if $(i, j) \in \{(tail, middle), (tail, head), (middle, head)\}$. 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. Because (2) controls a player's characteristics X_i, ε_{ij} is the measurement error of the subjective satisfaction variable. Note that observations within each player are not independent, and thus standard errors need to be adjusted for each player's cluster. The parameter of interest is β_2. If farmers optimize their water extraction level so as to care for their tail-enders, their demand should be smaller, which means that they are more likely to be satisfied. Therefore, the testable hypothesis is whether or not β_2 is positive. Also note that the games capture the incentive structure of head-enders, and thus no predictions can be drawn for the sign of β_3, which captures altruism or trust toward head-enders.

In using the trust game as a social capital variable, it is necessary to control for altruism and risk attitude. Cox (2004) shows that the behavior of the first mover in the trust game is confounded by altruism. For this reason, the results of the dictator game should be included. Regarding risk attitude, previous studies such as Schechter (2007) show that the first mover's behavior in the trust game confounds the level of trust with his/her own risk attitude, because how much money the second mover will return is uncertain for the first mover. In order to control for this effect, a risk attitude variable measured by the dice game is also included.

Another important control variable is the exit option. Previous studies such as Bardhan (2000) and Fujiie et al. (2005) show that irrigation management is difficult if users have access to income sources other than those related to irrigation. In order to control for the effect of exit options, the size of un-irrigated farmland is included. Some farmers had un-irrigated farmland, namely rain-fed or *chena* (slash-and-burn farming) plots, in addition to their irrigated plot. Because un-irrigated land size captures the effect of an exit option, a larger un-irrigated land size may lead to less cooperative behavior, and thus this variable is expected to have a negative effect on satisfaction. Because all of their land was acquired before 2007, this variable is free from the possibility that people added un-irrigated land because they were not satisfied with irrigation water usage.

Equation (2) is estimated for both the dictator and trust games as a benchmark, but this specification may be too naïve, because 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 prevents selfish behavior and decreases the demand for water. However, social capital itself also reflects the result of water allocation: people may work out their level of social capital mindful of the results of water allocation. In other words, not only does social capital affect satisfaction with water usage, but this satisfaction may also affect social capital.

In order to cope with this problem, it is necessary to find instruments that affect game results but that are not affected by satisfaction. Fortunately, the dataset includes the dictator and trust games not only in a situation where the player knows who the partner is, but also where the partner is not identified, except to say that they are in a different D-canal area. It is natural to assume that both cases share the inherent altruism or trust of the player, and thus there should be a positive correlation between them. In addition, because irrigation water is managed at the D-canal level, the water allocation problem does not occur between different D-canal areas, and so the results of water allocation and their satisfaction with it do not affect their altruism or trust toward those who are in different D-canal areas. Because the participants in the experiment were randomly chosen from each D-canal area, whether the partner is a head-ender or a tail-ender is determined exogenously, and therefore cross terms between these variables and altruism/trust toward a member of another D-canal also serve as valid instrumental variables (IVs).

4. Results

4.1 Descriptive statistics

Table 2 shows the descriptive statistics used for the main empirical study. Panel A shows the household characteristics. The binary variable for satisfaction in the main plot shows that 67% of the sample answered that they were satisfied with their water usage; in other words, one-third were not satisfied with the amount of water they used. This indicates that there is not enough irrigation water for everyone to have a sufficient amount, and thus there is a need to coordinate the water allocation. The weighted averages of the satisfaction variables are not substantially different from the satisfaction variables in the main plot.

Panel B shows the results of the artefactual field experiment. Interestingly, the amount sent decreases as the social distance between the partners increases.[9] Assuming additive separability, the difference between (a) and (b) shows the effect of whether or not the partner is identified, that between (b) and (c) shows the effect of sharing the same D-canal area, and that between (c) and (d) shows the effect of living in the same block.

9. Using the same dataset, Aoyagi et al. (2010) show that the fact of belonging to the same D-canal area and the partner being identified both have a positive effect on the amount sent in the trust game.

Panels A and B of Table 3 show the correlation of the game results for the different partners in the dictator and trust games, respectively. These results show that the amounts sent positively correlate with each other, which implies that all the amounts sent share the player's inherent altruism and trust.

Table 4 shows the determinants of the game results.[10] The dependent variable in column 1 is the result of the dictator game and in column 2 that of the trust game, and the specification in column 3 controls for the effect of altruism and risk attitude. Interestingly, whether the partner is in the head-end or the tail-end area relative to the player does not show a significant effect in any of the specifications. As previous studies have pointed out, both altruism and risk attitude have significantly positive effects on the results of the trust game. This result confirms the necessity for controlling for these effects in specification (2) using the results of the trust game.

4.2. Potential water conflict between head-enders and tail-enders

Before investigating the effect of social capital on irrigation water allocation, it is necessary to show whether water conflict between head-enders and tail-enders actually exists. If there is no such potential conflict, i.e., if there is not much difference in water availability between the head and tail, then social capital plays no role in the water allocation problem. As noted above, one-third answered that they were not satisfied with their water usage. In order to investigate whether there is a systematic difference in satisfaction between the head-end and the tail-end areas, model (2) is estimated without social capital variables.

Table 5 shows whether the location within each canal has an effect on satisfaction. The dependent variables are satisfaction in the main plot in columns 1 and 2, and average satisfaction weighted by plot size in columns 3 and 4. Note that the observations are not stacked because the game results are not included in the regression. The location coefficients

10. Also see Aoyagi et al. (2010) for a detailed discussion.

are all negative and statistically significant at the 10% level in columns 1 and 3, which means that farmers in areas farther downstream tend to be less satisfied with their water usage, and thus there is a potential difference in water availability between the head and tail.

4.3. Dictator game

Table 6 shows the effect of altruism on satisfaction with water usage using the results of the dictator game. Columns 1 and 2 show the results when satisfaction in the main plot is the dependent variable. The coefficient for the dictator game itself is insignificant in both specifications. Because the model controls for the case in which the partner is a head-ender or tail-ender relative to the player, this means that altruism toward people in the same part of the canal does not affect satisfaction. People with higher altruism toward tail-enders tend to be more satisfied with their water usage. This is consistent with the hypothesis that higher social capital prevents selfish behavior in water allocation. However, none of the coefficients are significant. Altruism toward head-enders does not show a significant effect. Because tail-enders do not need to consider head-enders when they decide how much water to extract, this result is reasonable. Once the social capital variables are controlled for, the coefficient for the location variable is not significant. This indicates that tail-enders are not necessarily less satisfied with water usage, and therefore, that irrigation water allocation between the head and tail is being conducted successfully.

As a robustness check, weighted averages of satisfaction variables are used as dependent variables in columns 3 and 4. Note that the results do not change qualitatively, except that un-irrigated land size shows significantly negative values. This negative sign shows the effect of an exit option, which is consistent with previous studies.

4.4. Trust game

Table 7 shows the results of the trust game. Columns 1 and 2 report the results using satisfaction in the main plot as the dependent variables. The effects of trust toward people in the same part of the canal and trust toward head-enders are insignificant. People with higher trust toward tail-enders tend to be more satisfied with their water usage in column 2. This also confirms the hypothesis that higher social capital decreases the water demand level and therefore leads to satisfaction with irrigation water usage. People with a higher risk attitude tend to be less satisfied with their water usage. This implies that risk-loving people tend to demand more water, which is more dangerous behavior because they might be punished by other members of the community. The other results are basically the same as in the previous subsection. The insignificance of the coefficient for the location variable indicates that tail-enders do not necessarily extract less water than they want.

Columns 3 and 4 report the results when the dependent variables are weighted averages. The qualitative results do not change except for the significantly negative coefficient for un-irrigated land size, which indicates the negative effect of the exit option.

4.5. Handling the reverse causality problem

In the previous subsections, altruism and trust toward tail-enders were seen to have positive effects on satisfaction with water usage. However, the effect is not robust, because the significance level is relatively low and insignificant in many specifications. This may reflect a reverse causality problem between satisfaction with water usage and altruism/trust. This subsection deals with this reverse causality problem by exploiting instrumental variables (IVs).

Table 8 and Table 9 show the IV regression results for the dictator game and the trust game, respectively. The first-stage F test rejects the null hypothesis at the 1% level for all endogenous variables and for all specifications. Note that the parameter of interest, altruism or trust toward tail-enders, is larger in the IV regression than in OLS. This indicates that the OLS estimators are downward biased, which means that satisfaction may negatively affect the level of social capital. Although this seems to be counter-intuitive, it is consistent with previous studies like Hayami (2009), which suggest that collective actions are likely to take place when resources are scarce. Because scarcity of resources requires coordination among players, it leads to social capital being enhanced.

In Table 8, altruism toward tail-enders shows a significantly positive effect when the dependent variables are measured by percentage. This implies that people with higher altruism toward tail-enders tend to demand less water because they care about tail-enders. Altruism toward people in the same part of the canal or altruism toward head-enders does not show significant effects on satisfaction. Social capital between head-enders and tail-enders is thus particularly important in irrigation water allocation. Un-irrigated land size had a negative effect on satisfaction levels, as it did in the OLS results.

In Table 9, higher trust toward tail-enders leads to a higher level of water satisfaction, which is consistent with the hypothesis. In contrast to the relatively ambiguous effect of altruism, trust toward tail-enders has a significantly positive effect in all specifications, and thus it has a more robust effect on the water allocation problem than altruism. As in the results above, trust toward people in the same part of the canal or trust toward head-enders does not show significant effects, and risk attitude and un-irrigated land size also show negative effects.

5. Concluding remarks

Social capital has been considered to be a key instrument for CPR management, but its effect among heterogeneous players is controversial. In irrigation management, one of the fundamental heterogeneities is the head-enders and tail-enders problem. This study bridges the existing gap between survey-based data and laboratory experiments, using social capital measured by field experiments as an independent variable. In addition, the natural experimental situation of the study site enables the potential difference in income or asset holdings between head-enders and tail-enders to be overcome. This study thus clearly estimates the effect of social capital on farmers’ satisfaction with irrigation water usage.

The important finding is that social capital with respect to tail-enders, and especially trust toward tail-enders, has a significantly positive effect on satisfaction with water usage. This is consistent with the hypothesis that head-enders optimize their water demand so as to care for their tail-enders. Another important finding is that OLS estimators for these social capital variables are downward biased. This confirms the hypothesis that scarcity of resources induces social capital accumulation.

The difference in the results between altruism and trust implies an important feature of irrigation management. In the case of altruism, a player's utility is higher just because his/her partner's payoff improves; in contrast, a player trusts his/her partner in the sense that he/she expects a positive return from the partner. In irrigation management, cooperation between head-enders and tail-enders is crucially important. For this reason, by leaving enough water for the tail-enders, head-enders anticipate better cooperation with tail-enders.

In addition to the main results, the significantly positive effect of the dictator and trust games supports the validity of using experimental data as a measure of social capital. Taking the irrigation water allocation problem for head-enders to be natural dictator game or trust game, the findings of this paper show a strong link between the artefactual field experiment and actual economic transactions.

Appendix

One possible concern is whether the subjective answers regarding water usage reflect the actual situation. In order to address this problem, the production function of paddies is estimated including the variables noted here. The left-hand-side variable is the log of the value-added of paddy production. As there were no agricultural asset value data in the latest survey, these are replaced with the mean value in the previous two surveys, which were conducted in the dry and rainy seasons in 2006 and 2007. For the labor input measure, the number of household members whose primary or secondary occupation is farming their own land is included, as well as the log of the total payment to hired labor. Table A1 shows the results.

For all specifications, land size has positive effect on production. Capital and labor input are not significant; this is because there is a strong colinearity between these variables. Location within each canal does not have significant effect on production, which indicates that the irrigation water is well-managed.

For satisfaction variables, all coefficients show a positive sign and are significant in columns 2 and 4. Note that if the hypothesis is correct and social capital enforces self-restraint, it does not necessarily have a significant effect on individual agricultural production.[11] Farmers with higher social capital demand less water, which can result in satisfaction with water usage having an insignificant effect on production. In addition, there might be attenuation bias if there is measurement error in the subjective answers. Bearing in mind these possibilities, the positive but not significant sign may still indicate that the satisfaction variable captures actual water usage.

11. Fafchamps (2006) explains the same problem through the example of fishing grounds.

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Figure 1: Sampling structure of original dataset (from Aoyagi et al. 2010)

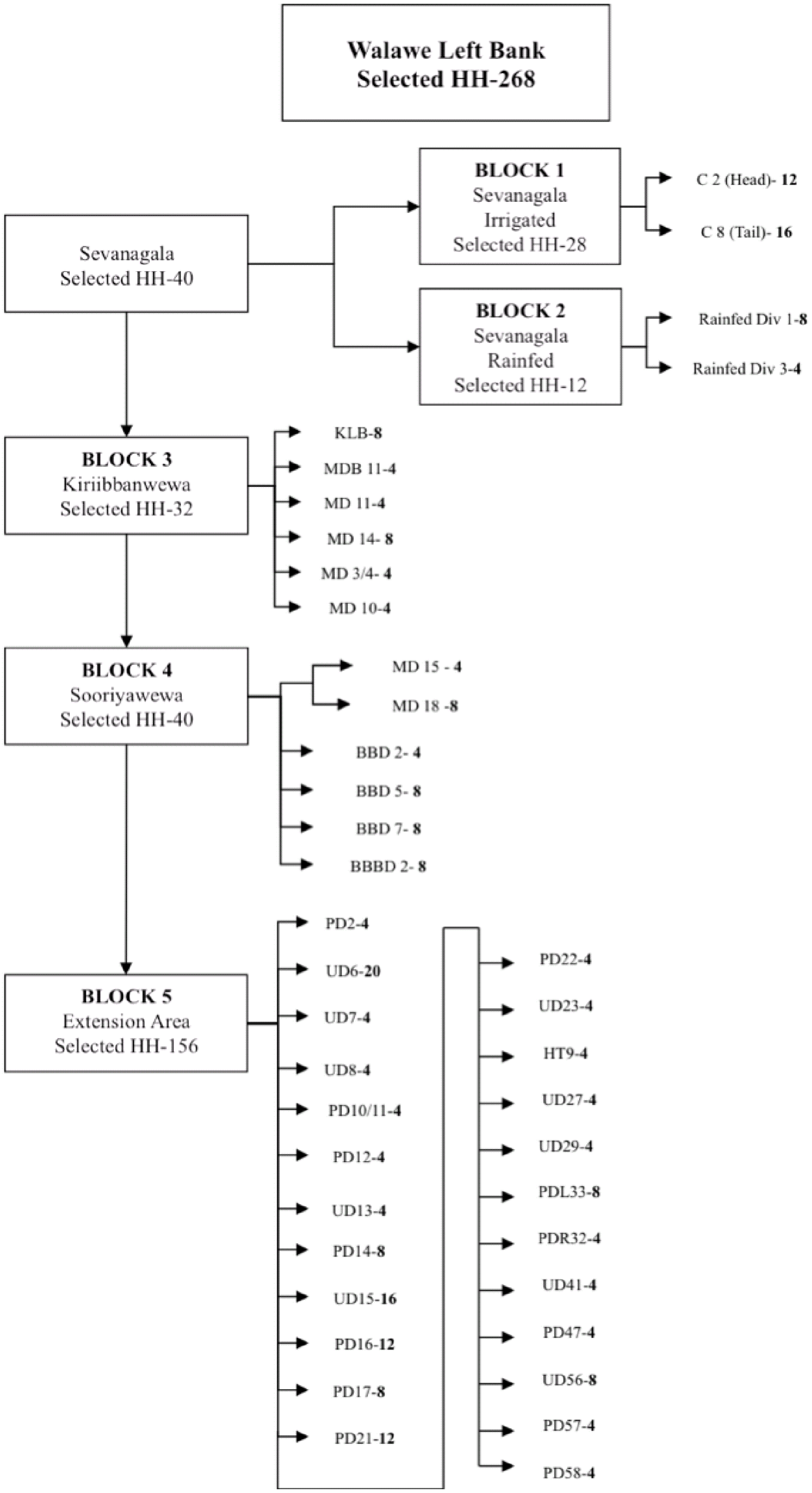

Figure 2: CDF of log (income)

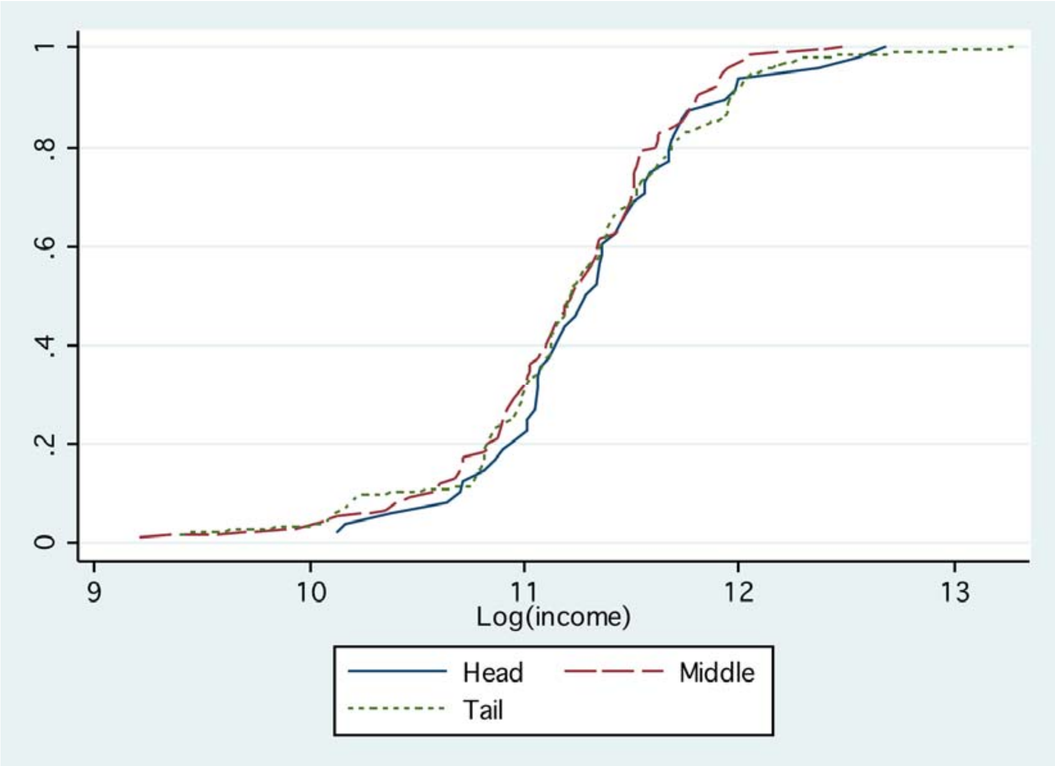

Figure 3: CDF of total irrigated plot size

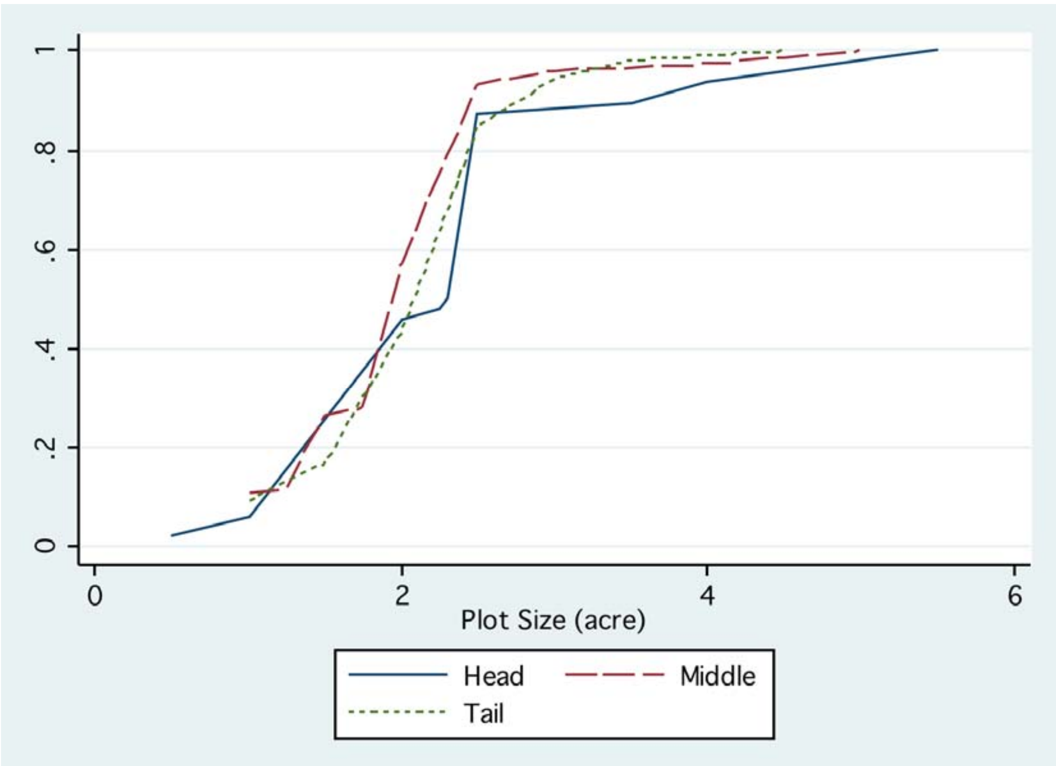

Table 1: Payoff in dice game (investment = x)

Red	Blue	Green	Yellow	Black	White
0	0.5x	x	1.5x	2x	2.5x

Table 2: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.
Panel A: Household Characteristics			
Satisfaction (binary): main plot	547	0.6709324	0.4703047
Satisfaction (%): main plot	547	89.08592	18.44917
Satisfaction (binary): weighted average	544	0.6737482	0.4575363
Satisfaction (%): weighted average	544	88.86633	18.02452
Location (1 = head, 2 = middle, 3 = tail)	552	2.039855	0.7562482
Log (plot size)	552	0.6861963	0.2943527
Log (total plot size)	552	.7495168	0.3499816
Log (un-irrigated land size)	552	-4.346148	1.091339
Household head participated in the experiment	552	0.7210145	0.4489072
Age of household head	549	52.49362	10.5643
Female household head	549	0.0928962	0.2905516
Education of household head	540	6.214815	3.24997
Panel B: Artefactual Field Experiment			
Vs_tail	552	0.3115942	0.463565
Vs_head	552	0.3097826	0.4628233
Dictator Game			
(a) Same D-canal (non-anonymous)	552	160.6884	111.1068
(b) Same D-canal (anonymous)	552	137.1377	104.8175
(c) Different D-canal, same block (anonymous)	552	102.4457	98.66807
(d) Different block (anonymous)	552	80.07246	91.97172
Trust Game			
(a) Same D-canal (non-anonymous)	552	211.5942	130.6885
(b) Same D-canal (anonymous)	552	160.0543	120.1307
(c) Different D-canal, same block (anonymous)	552	128.5326	126.0031
(d) Different block (anonymous)	552	109.5109	118.5788
Dice game	552	205.7971	119.4471

Note: For all variables in logarithm, 0.01 is added before taking the log.

Table 3: Correlation of the game results among different social distances

Panel A: Dictator Game

	(a)	(b)	(c)	(d)
(a)	1			
(b)	0.4634	1		
(c)	0.4018	0.3748	1	
(d)	0.4926	0.5668	0.8039	1

Panel B: Trust Game

	(a)	(b)	(c)	(d)
(a)	1			
(b)	0.4905	1		
(c)	0.5367	0.5526	1	
(d)	0.5474	0.4867	0.7777	1

Note: (a) same D-canal (non-anonymous), (b) same D-canal (anonymous), (c) different D-canal, same block (anonymous), (d) different block (anonymous).

Table 4: Determinants of the results of the dictator and trust games

VARIABLES	(1) Dictator Game	(2) Trust Game	(3) Trust Game
Vs_head	8.870	11.22	2.011
	(13.25)	(16.29)	(13.16)
Vs_tail	12.54	1.548	-8.519
	(13.06)	(14.13)	(11.62)
Dictator game			0.665***
			(0.0627)
Dice game			11.52*
			(6.104)
Household head	-28.02	-27.67	-7.886
	(19.08)	(20.85)	(14.94)
Age of household head	0.645	1.458	0.900
	(0.770)	(0.909)	(0.703)
Female household head	32.84	37.16	21.58
	(32.07)	(32.90)	(27.58)
Education of household head	2.659	-1.449	-2.909
	(2.262)	(2.646)	(1.883)
Constant	119.1***	157.0***	58.91
	(45.20)	(55.65)	(41.30)
Observations	540	540	540
R-squared	0.028	0.028	0.375

Cluster-adjusted standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Potential water conflict between head-enders and tail-enders

VARIABLES	(1) OLS Main plot Satisfaction	(2) OLS Main plot Satisfaction (%)	(3) OLS Weighted average Satisfaction	(4) OLS Weighted average Satisfaction (%)
Location (1 = head, 2 = middle, 3 = tail)	-0.0890*	-1.012	-0.0854*	-1.421
	(0.0507)	(1.722)	(0.0510)	(1.794)
Log (plot size)	-0.143	-5.390		
	(0.110)	(4.299)		
Log (total plot size)			-0.0517	-3.294
			(0.0879)	(3.460)
Log (un-irrigated land size)	-0.0374	-2.472	-0.0491*	-3.078*
	(0.0282)	(1.900)	(0.0258)	(1.855)
Household head	0.0329	-1.248	0.0155	-0.816
	(0.105)	(3.592)	(0.105)	(3.640)
Age of household head	0.000462	0.00163	0.000441	-0.0121
	(0.00454)	(0.168)	(0.00450)	(0.164)
Female household head	0.0926	0.130	0.0530	-1.420
	(0.138)	(5.757)	(0.145)	(6.005)
Education of household head	0.0163	0.467	0.0145	0.261
	(0.0124)	(0.503)	(0.0123)	(0.504)
Constant	-0.0448	51.14***	0.0863	58.41***
	(0.304)	(14.06)	(0.309)	(14.58)
D-canal dummies	YES	YES	YES	YES
Observations	183	183	182	182
R-squared	0.399	0.415	0.372	0.382

Cluster-adjusted standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

Table 6: Dictator game (OLS)

VARIABLES	(1) OLS Main plot Satisfaction (binary)	(2) OLS Main plot Satisfaction (%)	(3) OLS Weighted average Satisfaction (binary)	(4) OLS Weighted average Satisfaction (%)
Dictator game	-0.00319	0.440	-0.00463	0.572
	(0.0289)	(1.078)	(0.0284)	(1.067)
Vs_tail × dictator game	0.00490	1.255	0.00757	1.195
	(0.0232)	(0.795)	(0.0233)	(0.813)
Vs_head × dictator game	-0.0267	-1.032	-0.0292	-0.968
	(0.0250)	(0.885)	(0.0247)	(0.876)
Location (1 = head, 2 = middle, 3 = tail)	-0.0686	0.591	-0.0619	0.0834
	(0.0506)	(1.676)	(0.0501)	(1.717)
Log (plot size)	-0.144	-5.209		
	(0.0991)	(3.795)		
Log (total plot size)			-0.0495	-3.321
			(0.0802)	(3.118)
Log (un-irrigated land size)	-0.0383	-2.480	-0.0503**	-3.081*
	(0.0252)	(1.702)	(0.0228)	(1.655)
Household head	0.0240	-1.173	0.00918	-0.674
	(0.0964)	(3.287)	(0.0965)	(3.304)
Age of household head	0.000465	-0.00547	0.000398	-0.0194
	(0.00418)	(0.152)	(0.00414)	(0.147)
Female household head	0.104	0.299	0.0597	-1.317
	(0.124)	(5.210)	(0.131)	(5.437)
Education of household head	0.0180	0.506	0.0161	0.286
	(0.0116)	(0.469)	(0.0115)	(0.468)
Constant	-0.0802	46.98***	0.0423	54.46***
	(0.280)	(12.52)	(0.285)	(13.10)
D-canal dummies	YES	YES	YES	YES
Observations	535	535	532	532
R-squared	0.397	0.411	0.367	0.374

Cluster-adjusted standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Note: The results of the dictator game, trust game, and dice game are divided by 100 for scaling.

Table 7: Trust game (OLS)

VARIABLES	(1) OLS Main plot Satisfaction (binary)	(2) OLS Main plot Satisfaction (%)	(3) OLS Weighted average Satisfaction (binary)	(4) OLS Weighted average Satisfaction (%)
Trust game	0.00836	-0.0802	0.00195	-0.337
	(0.0239)	(0.996)	(0.0243)	(1.060)
Vs_tail × trust game	0.0218	1.260**	0.0208	1.168*
	(0.0166)	(0.581)	(0.0166)	(0.605)
Vs_head × trust game	-0.00898	0.238	-0.00246	0.524
	(0.0181)	(0.731)	(0.0179)	(0.731)
Dictator game	-0.00473	1.068	-0.00236	1.365
	(0.0311)	(1.122)	(0.0307)	(1.143)
Dice game	-0.0425	-2.369**	-0.0421	-2.403**
	(0.0286)	(1.082)	(0.0280)	(1.038)
Location (1 = head, 2 = middle, 3 = tail)	-0.0571	0.212	-0.0615	-0.561
	(0.0472)	(1.593)	(0.0471)	(1.599)
Log (plot size)	-0.156	-5.714		
	(0.102)	(3.713)		
Log (total plot size)			-0.0551	-3.523
			(0.0827)	(3.162)
Log (un-irrigated land size)	-0.0362	-2.336	-0.0477**	-2.929*
	(0.0247)	(1.660)	(0.0227)	(1.631)
Household head	0.0290	-1.046	0.0132	-0.584
	(0.0951)	(3.294)	(0.0952)	(3.278)
Age of household head	0.000636	0.0118	0.000649	-0.000754
	(0.00416)	(0.151)	(0.00414)	(0.147)
Female household head	0.0698	-1.379	0.0302	-2.833
	(0.127)	(5.189)	(0.134)	(5.467)
Education of household head	0.0170	0.454	0.0150	0.224
	(0.0116)	(0.455)	(0.0115)	(0.452)
Constant	-0.0427	51.36***	0.105	59.57***
	(0.277)	(12.40)	(0.281)	(12.83)
D-canal dummies	YES	YES	YES	YES
Observations	535	535	532	532
R-squared	0.406	0.425	0.375	0.390

Cluster-adjusted standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1
Note: The results of the dictator game, trust game, and dice game are divided by 100 for scaling.

Table 8: Dictator game (IV)

VARIABLES	(1) IV Main plot Satisfaction (binary)	(2) IV Main plot Satisfaction (%)	(3) IV Weighted average Satisfaction (binary)	(4) IV Weighted average Satisfaction (%)
Dictator game	-0.00273	1.954	0.0179	2.576
	(0.0557)	(2.161)	(0.0538)	(2.124)
Vs_tail × dictator game	0.0342	2.078**	0.0375	2.252**
	(0.0269)	(1.040)	(0.0266)	(1.057)
Vs_head × dictator game	-0.0500	-1.681	-0.0389	-1.579
	(0.0340)	(1.374)	(0.0325)	(1.386)
Location (1 = head, 2 = middle, 3 = tail)	-0.0310	1.737	-0.0322	1.378
	(0.0513)	(1.842)	(0.0514)	(1.856)
Log (plot size)	-0.139	-5.055		
	(0.0932)	(3.543)		
Log (total plot size)			-0.0516	-3.428
			(0.0756)	(3.035)
Log (un-irrigated land size)	-0.0395*	-2.457	-0.0499**	-3.036**
	(0.0237)	(1.595)	(0.0215)	(1.535)
Household head	0.0274	-0.631	0.0211	0.0994
	(0.0910)	(3.066)	(0.0908)	(3.034)
Age of household head	8.07e-05	-0.0217	8.47e-06	-0.0392
	(0.00394)	(0.139)	(0.00383)	(0.134)
Female household head	0.105	0.315	0.0612	-1.265
	(0.119)	(4.860)	(0.123)	(5.056)
Education of household head	0.0175	0.442	0.0146	0.195
	(0.0109)	(0.436)	(0.0109)	(0.436)
Constant	-0.152	43.23***	-0.0371	50.05***
	(0.267)	(11.74)	(0.267)	(12.18)
D-canal dummies	YES	YES	YES	YES
First stage F-stat				
Dictator game	16.69***	16.69***	16.92***	16.92***
Vs_tail × dictator game	40.84***	40.84***	40.10***	40.10***
Vs_head × dictator game	31.66***	31.66***	32.43***	32.43***
Observations	535	535	532	532
R-squared	0.392	0.401	0.360	0.357

Cluster-adjusted standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: The results of the dictator game, trust game, and dice game are divided by 100 for scaling.

Endogenous variable: dictator game, vs_tail × dictator game, vs_head × dictator game.

Instrument: dictator game (different D-canal), vs_tail × dictator game (different D-canal), vs_head × dictator game (different D-canal).

Table 9: Trust game (IV)

VARIABLES	(1) IV Main plot Satisfaction (binary)	(2) IV Main plot Satisfaction (%)	(3) IV Weighted average Satisfaction (binary)	(4) IV Weighted average Satisfaction (%)
Trust game	0.114	1.387	0.0970	0.744
	(0.101)	(3.606)	(0.104)	(3.703)
Vs_tail × trust game	0.0531**	2.340***	0.0572**	2.596***
	(0.0234)	(0.865)	(0.0236)	(0.899)
Vs_head × trust game	-0.0401	-0.804	-0.0214	-0.549
	(0.0312)	(1.026)	(0.0290)	(1.050)
Dictator game	-0.0905	1.826	-0.0513	3.031
	(0.118)	(4.325)	(0.117)	(4.280)
Dice game	-0.0487	-3.013**	-0.0573*	-3.227***
	(0.0312)	(1.171)	(0.0305)	(1.132)
Location (1 = head, 2 = middle, 3 = tail)	-0.00497	2.297	-0.0133	1.887
	(0.0548)	(1.864)	(0.0541)	(1.845)
Log (plot size)	-0.215*	-6.499		
	(0.115)	(4.026)		
Log (total plot size)			-0.0786	-3.868
			(0.0876)	(3.249)
Log (un-irrigated land size)	-0.0413	-2.311	-0.0510**	-2.844*
	(0.0259)	(1.548)	(0.0245)	(1.505)
Household head	0.0536	-0.110	0.0452	0.604
	(0.0905)	(3.139)	(0.0890)	(3.052)
Age of household head	-0.000225	-0.00911	-0.000271	-0.0238
	(0.00399)	(0.134)	(0.00389)	(0.130)
Female household head	0.0227	-2.610	-0.0151	-4.028
	(0.126)	(5.185)	(0.130)	(5.393)
Education of household head	0.0206*	0.432	0.0172	0.164
	(0.0120)	(0.460)	(0.0120)	(0.456)
Constant	-0.223	45.37***	-0.0859	52.85***
	(0.290)	(11.97)	(0.294)	(12.43)
D-canal dummies	YES	YES	YES	YES
First stage F-stat				
Trust game	28.87***	28.87***	29.92***	29.92***
Vs_tail × trust game	71.17***	71.17***	69.36***	69.36***
Vs_head × trust game	50.77***	50.77***	54.25***	54.25***
Dictator game	24.29***	24.29***	31.12***	31.12***
Observations	535	535	532	532
R-squared	0.357	0.404	0.327	0.359

Cluster-adjusted standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: The results of the dictator game, trust game, and dice game are divided by 100 for scaling.

Endogenous variable: trust game, vs_tail × trust game, vs_head × trust game, dictator game.

Instrument: trust game (different D-canal), vs_tail × trust game (different D-canal), vs_head × trust game (different D-canal), dictator game (different D-canal).

Table A1: Estimation of paddy production function

VARIABLES	(1) Log (value added)	(2) Log (value added)	(3) Log (value added)	(4) Log (value added)
Satisfaction (binary): main plot	0.127			
	(0.0963)			
Satisfaction (%): main plot		0.00551**		
		(0.00255)		
Satisfaction (binary): weighted			0.108	
			(0.0989)	
Satisfaction (%): weighted average				0.00436*
				(0.00257)
Log (cultivated area)	0.907***	0.896***	0.914***	0.901***
	(0.0900)	(0.0870)	(0.0866)	(0.0836)
Log (agricultural asset)	0.0430	0.0512	0.0494	0.0580
	(0.0640)	(0.0627)	(0.0641)	(0.0638)
Log (hired labor)	0.0490	0.0446	0.0426	0.0366
	(0.0612)	(0.0603)	(0.0614)	(0.0614)
Members in agriculture	0.0348*	0.0313	0.0329	0.0310
	(0.0207)	(0.0198)	(0.0207)	(0.0201)
Location (1 = head, 2 = middle, 3 = tail)	0.00316	0.00400	-0.0148	-0.0161
	(0.0618)	(0.0597)	(0.0622)	(0.0606)
Age of household head	-0.00149	-0.00143	-0.00174	-0.00183
	(0.00377)	(0.00371)	(0.00380)	(0.00377)
Female household head	0.0798	0.113	0.105	0.124
	(0.162)	(0.159)	(0.163)	(0.157)
Education of household head	-0.00860	-0.00866	-0.00952	-0.00960
	(0.0136)	(0.0136)	(0.0135)	(0.0135)
Constant	9.789***	9.444***	9.832***	9.560***
	(0.415)	(0.451)	(0.418)	(0.455)
D-canal dummies	YES	YES	YES	YES
Observations	166	166	165	165
R-squared	0.746	0.753	0.749	0.753

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Abstract (in Japanese)

要約

本論文は灌漑用水路における上流下流間の資源配分に対し、社会関係資本が与える影響を検証したものである。社会関係資本は共有資源管理の重要な手段であると考えられているが、プレーヤー間に異質性があった場合のその効果については明らかではない。灌漑管理については、上流と下流との間の用水配分はそのような深刻な問題の一つである。本論文では JICA によって収集された経済学実験及び通常の家計調査データを用い、特に下流農民に対する信頼という意味での社会関係資本が上流農民の用水使用の満足度にプラスの影響を与えていることを発見した。上流農民にとっての灌漑用水配分におけるインセンティブ構造が独裁者ゲームや信頼ゲームのインセンティブ構造に類似していることから、この結果は実験的手法によって計測された社会関係資本の妥当性を支持するものでもある。さらに、本論文では主観的満足度と社会関係資本との間の同時方程式バイアスにも対処しており、この結果 OLS 推定量に下方バイアスがかかっていることを発見した。この結果は、資源の希少性が社会関係資本を高めるという仮説と整合的である。

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