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

Takeshi Aida
Graduate School of Economics, University of Tokyo
JSPS Research Fellow
aidatakeshi@gmail.com

Abstract

This paper investigates the effect of social capital between irrigation canal head-enders and tail-enders on their water allocation problem. In irrigation management, the water allocation problem between head-enders and tail-enders is one of the 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 social capital.

Keywords: Social capital; irrigation; field experiment; head-enders and tail-enders; validity
JEL Classification Number: C93, O12, O13, Q15

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 (Bowles and Gintis 2002; Hayami 2009).

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. Among these heterogeneities, the specific problem for irrigation management is the 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.

Many empirical researches have focused on this theme and found cooperation between head-enders and tail-enders is difficult (e.g., Wade 1988; Tang 1992; Ostrom and Gardner 1993; Fujiie et al. 2005; Nakano and Otsuka 2011). However, these survey-based analyses cannot directly identify the effect of social capital on the collective action problem because of the difficulty of measuring the level of social capital. In addition to these analyses, there is a growing literature on this theme using economic experiments such as “irrigation game” (e.g., Cardenas et al. 2008) as well as conventional (or slightly modified) bilateral transaction games (Jack 2009; D’Exelle et al. 2012). However, 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. 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 by using desirable dataset for this purpose. Another contribution is to show the validity of experimentally measured social capital. This paper tests the validity of the dictator game and the trust game, which are most standard experiment to measure social capital (Cardenas and Carpenter 2008; Camerer and Fehr 2004; Levitt and List 2007), by demonstrating links between the results of these experiments and actual economic transactions. This is because the incentive structure of irrigation water allocation for head-enders closely resembles those in the dictator and trust games.

2. Setting of Natural and Field Experiment

This paper uses a dataset from an irrigation project in Sri Lanka, which was originally collected by JICA. The study site is Walawe Left Bank (WLB), located in the southern part of Sri Lanka. The government launched construction of irrigation canals using Japanese ODA loans in 1997. By the end of 2008, almost every household had acquired access to irrigation facilities. 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. Among these, this study uses the last household survey data combined with artefactual field experiment data.

The study site possesses unique natural experimental characteristics that are ideal for this study. Regarding to the irrigated land, lottery based allocation was employed for new settlers. Re-settlers who have been in the study site before the irrigation construction were allowed to select a land from their former cultivation area. However, even those re-settlers did not have a chance to claim which D-canals, which are the secondary canals to draw water from the main canal, they wanted to be assigned to. Thus land allocation was exogenously determined at D-canal level, and independent from observable and unobservable household characteristics. In fact, 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.

The experiments comprised the dictator game, trust game, and risk game. The sample was 268 farmers randomly selected from the survey area. 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. Then, using an answer sheet, they were asked to fill in the 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 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).

3. Empirical Strategy

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 survey period. 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.[1]

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. 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.

In the case of pure self-interest, head-end farmers 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. 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

[1] The percentage satisfaction variable is given as 100 if they answered that they were satisfied with their water usage. As shown in the original version, this upward censoring does not affect qualitative results of this paper.

into account, the game results distinguish whether the partner is at the head or the tail relative to the player.

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:

$$Satisfaction_i = \alpha + \beta_1 SC_{ij} + \beta_2 vs\_tail_{ij} \times SC_{ij} + \beta_3 vs\_head_{ij} \times SC_{ij} + \gamma X_i + DC_i + \varepsilon_{ij} \quad (1)$$

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. 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 correlation within individuals. 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.

Equation (1) 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. In order to cope with this problem, it is necessary to find instruments that affect game results but that does not directly affect satisfaction. Fortunately, the dataset also includes the dictator and trust games in a situation 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 directly affect their altruism or trust toward those who are in different D-canal areas.

4. Estimation Results

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. Column (1) and (2) of Table I shows whether the location within each canal has an effect on satisfaction. Note that the observations are not stacked because the game results are not included in the regression. The location coefficients are both negative and statistically significant at the 10% level in columns 2, 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. Note that these results are unconditional on social capital variables, which is often the case with the studies uses observational data only. Whether this significant effect of location within irrigation canals is preserved even after controlling for social capital is an important question to compare with the results of previous survey-based studies.

Column (3) and (4) show the results of altruism on satisfaction level by OLS and (5) and (6) column by IV. Although altruism toward tail-enders has positive effect, the signs are insignificant in OLS. In IV estimation, those coefficients are still positive, and significant when the dependent variable is percentage. Intriguingly, the magnitude of coefficients on this variable is larger in IV estimation than in OLS, indicating that the reversed effect of satisfaction level on altruism is negative. Although this seems to be counter-intuitive, it is consistent with previous studies like Hayami (2009) and Nakano and Otsuka (2011), which suggest that collective actions are likely to take place when resources are scarce. In addition, insignificant sign on canal location shows that farmers in downstream area are not necessarily less satisfied with water usage once social capital level is controlled for.

The last four columns show the results using trust game results as social capital measure. Note that the results of dictator game and risk game are included, because previous studies shows that the results of trust game confounded with altruism and risk preferences (Cox 2004; Schechter 2007). In contrast to relatively ambiguous effect of altruism, trust toward tail-enders has significantly positive effect except for column (7). These results are also consistent with the main hypothesis, thus social capital acts as an instrument for irrigation water allocation. The coefficients in IV are larger than in OLS, which is consistent with the results using dictator game results.

The dependent variables used so far are subjective assessment on each farmer's water usage level. Although the use of subjective measures is becoming more common in economics, it is still necessary to show the link between the satisfaction level variables and the actual agricultural productivity. The other concern is the possibility of another interpretation of the results in the previous subsections: people who are more satisfied with their water use are the ones with higher productivity and consequently higher income, thus their marginal utility from irrigation water is low. If this is the case, significantly positive coefficient on altruism and trust toward tail-enders is spurious because productivity is omitted from the equation. Although not shown in this short version, the original paper estimates the model including total amount of paddy produced. The results show significantly positive link between satisfaction level and productivity, validating this subjective measure. Also, the qualitative results remain unchanged after including productivity, which rejects the alternative hypothesis of spurious correlation.

4. Concluding Remarks

Social capital has been considered to be a key instrument for CPR management, but there is little clear evidence on its effect among heterogeneous players. In irrigation management, one of the fundamental heterogeneities is the head-enders and tail-enders problem. Although many studies have been investigating this problem, the existing studies use only observational or experimental data, and thus internal and external validity is still an important issue to be addressed. This study bridges the existing gap between these studies, 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, 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.

References

Aoki, Masahiko and Yujiro Hayami (eds.) (2001) *Communities and Markets in Economic Development*. Oxford: Oxford University Press.

Aoyagi, Keitaro, Masahiro Shoji, and Yasuyuki Sawada (2012) "Does Infrastructure Facilitate Social Capital Accumulation? Evidence from Natural and Artefactual Field Experiments in Sri Lanka." Mimeo.

Bardhan, Pranab (2000) "Irrigation and Cooperation: An Empirical Analysis of 48 Irrigation Communities in South India." *Economic Development and Cultural Change* 48, pp. 847–865.

Bardhan, Pranab and Jeff Dayton-Johnson (2002) "Unequal Irrigators: Heterogeneity and Commons

Management in Large-Scale Multivariate Research." In National Research Council (eds.) *The Drama of the Commons,* pp. 87–112. Washington, D.C.: National Academy Press.

Bowles, Samuel and Herbert Gintis (2002) "Social Capital and Community Governance," *Economic Journal* 112 (483), pp.419–436.

Camerer, Colin F., and Ernst Fehr (2004) "Measuring Social Norms and Preferences Using Experimental Games: A Guide for Social Scientists." In Henrich, Joseph, Robert Boyd, Samuel Bowles, Colin F. Camerer, Ernst Fehr, and Herbert Gintis (eds.) *Foundations of Human Sociality: Economic Experiments and Ethnographic Evidence from Fifteen Small-Scale Societies*, pp. 55–95. Oxford: Oxford University Press.

Cardenas, Juan Camilo, Marco Janssen, and Francois Bousquet (2008) "Dynamics of Rules and Resources: Three New Field Experiments on Water, Forests and Fisheries." In List, John and Michael Price (eds.) *Handbook on Experimental Economics and the Environment*. Northampton, Massachusetts: Edward Elgar Publishing (forthcoming).

Cardenas, Juan Camilo and Jeffry Carpenter (2008) "Behavioural Development Economics: Lessons from Field Labs in the Developing World." *Journal of Development Studies* 44(3), pp. 311–338.

D'Exelle, Ben, Els Lecoutere and Bjorn van Campenhout (2012) "Equity-efficiency Trade-offs in Irrigation Water Sharing: Evidence from a Field Lab in Rural Tanzania," *World Development* (forthcoming)

Cox, James C. (2004) "How to identify trust and reciprocity." *Games and Economic Behavior* 46, pp. 260–281.

Fujiie, Masako, Yujiro Hayami, and Masao Kikuchi (2005) "The conditions of collective action for local commons management: the case of irrigation in the Philippines." *Agricultural Economics* 33, pp. 179–189.

Hardin, Garrett (1968) "The Tragedy of the Commons." *Science* 162, pp. 1243–1248.

Hayami, Yujiro (2009) "Social Capital, Human Capital and the Community Mechanism: Toward a Conceptual Framework for Economists." *Journal of Development Studies* 45(1), pp. 96–123.

Jack, B. Kelsey (2009) "Upstream–downstream transactions and watershed externalities: Experimental evidence from Kenya," *Ecological Economics* 68, pp.1813-1824.

Levitt, Steven D. and John A. List (2007) "What Do Laboratory Experiments Measuring Social Preferences Reveal about the Real World?" *Journal of Economic Perspectives* 21(2), pp. 153–174.

Nakano, Yuko and Keijiro Otsuka (2011) "Determinants of household contributions to collective irrigation management: The case of the Doho Rice Scheme in Uganda." *Environment and Development Economics* 16, pp.527–551

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

Ostrom, Elinor and Roy Gardner (1993) "Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work." *Journal of Economic Perspectives* 7(4), pp. 93–112.

Roe, Brian E. and David R. Just (2009) "Internal and External Validity in Economics Research: Tradeoffs between Experiments, Field Experiments, Natural Experiments, and Field Data," *American Journal of Agricultural Economics* 91, pp. 1266–1271.

Schechter, Laura (2007) "Traditional trust measurement and the risk confound: An experiment in rural Paraguay." *Journal of Economic Behavior & Organization* 62, pp. 272–292.

Schoengold, Karina and David Zilberman (2006) "The Economics of Water, Irrigation, and Development." In Evenson, Robert E. and Prabhu Pingali (eds.) *Handbook of Agricultural Economics*. Amsterdam: North Holland.

Tang, Shui Yan (1992) *Institutions and collective action: Self-governance in irrigation*. San Francisco: Institute for Contemporary Studies.

Wade, Robert (1988) *Village republics: Economic conditions for collective action in south India*. Cambridge: Cambridge University Press.

Table I: Main Empirical Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	OLS	OLS	OLS	IV	IV	OLS	OLS	IV	IV
SC	NA	NA	Dictator	Dictator	Dictator	Dictator	Trust	Trust	Trust	Trust
VARIABLES	Binary	%	Binary	%	Binary	%	Binary	%	Binary	%
Dictator game			-0.00319	0.440	-0.00273	1.954	0.00836	-0.0802	0.114	1.387
			(0.0289)	(1.078)	(0.0557)	(2.161)	(0.0239)	(0.996)	(0.101)	(3.606)
Trust game							-0.00473	1.068	-0.0905	1.826
							(0.0311)	(1.122)	(0.118)	(4.325)
Vs_tail × SC			0.00490	1.255	0.0342	2.078**	0.0218	1.260**	0.0531**	2.340***
			(0.0232)	(0.795)	(0.0269)	(1.040)	(0.0166)	(0.581)	(0.0234)	(0.865)
Vs_head × SC			-0.0267	-1.032	-0.0500	-1.681	-0.00898	0.238	-0.0401	-0.804
			(0.0250)	(0.885)	(0.0340)	(1.374)	(0.0181)	(0.731)	(0.0312)	(1.026)
Risk game							-0.0425	-2.369**	-0.0487	-3.013**
							(0.0286)	(1.082)	(0.0312)	(1.171)
Location	-0.0890*	-1.012	-0.0686	0.591	-0.0310	1.737	-0.0571	0.212	-0.00497	2.297
(1 = head, 2 = middle, 3 = tail)	(0.0507)	(1.722)	(0.0506)	(1.676)	(0.0513)	(1.842)	(0.0472)	(1.593)	(0.0548)	(1.864)
Log (plot size)	-0.143	-5.390	-0.144	-5.209	-0.139	-5.055	-0.156	-5.714	-0.215*	-6.499
	(0.110)	(4.299)	(0.0991)	(3.795)	(0.0932)	(3.543)	(0.102)	(3.713)	(0.115)	(4.026)
Log (un-irrigated land size)	-0.0374	-2.472	-0.0383	-2.480	-0.0395*	-2.457	-0.0362	-2.336	-0.0413	-2.311
	(0.0282)	(1.900)	(0.0252)	(1.702)	(0.0237)	(1.595)	(0.0247)	(1.660)	(0.0259)	(1.548)
Household head	0.0329	-1.248	0.0240	-1.173	0.0274	-0.631	0.0290	-1.046	0.0536	-0.110
	(0.105)	(3.592)	(0.0964)	(3.287)	(0.0910)	(3.066)	(0.0951)	(3.294)	(0.0905)	(3.139)
Age of household head	0.000462	0.00163	0.000465	-0.00547	8.07e-05	-0.0217	0.000636	0.0118	-0.000225	-0.00911
	(0.00454)	(0.168)	(0.00418)	(0.152)	(0.00394)	(0.139)	(0.00416)	(0.151)	(0.00399)	(0.134)
Female household head	0.0926	0.130	0.104	0.299	0.105	0.315	0.0698	-1.379	0.0227	-2.610
	(0.138)	(5.757)	(0.124)	(5.210)	(0.119)	(4.860)	(0.127)	(5.189)	(0.126)	(5.185)
Education of household head	0.0163	0.467	0.0180	0.506	0.0175	0.442	0.0170	0.454	0.0206*	0.432
	(0.0124)	(0.503)	(0.0116)	(0.469)	(0.0109)	(0.436)	(0.0116)	(0.455)	(0.0120)	(0.460)
Constant	-0.0448	51.14***	-0.0802	46.98***	-0.152	43.23***	-0.0427	51.36***	-0.223	45.37***
	(0.304)	(14.06)	(0.280)	(12.52)	(0.267)	(11.74)	(0.277)	(12.40)	(0.290)	(11.97)
D-canal dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
First stage F-stat										
Dictator game					16.69***	16.69***			24.29***	24.29***
Trust game									28.87***	28.87***
Vs_tail × SC					40.84***	40.84***			71.17***	71.17***
Vs_head × SC					31.66***	31.66***			50.77***	50.77***
Observations	183	182	535	535	535	535	535	535	535	535
R-squared	0.399	0.372	0.397	0.411	0.392	0.401	0.406	0.425	0.357	0.404

Standard errors in parentheses are adjusted for correlations within individuals. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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

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

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