Is information the key to improved equity in Pakistan's irrigation system? Evidence from an experimental game in Punjab

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Introduction

The massive irrigation system of Pakistan's Indus Basin (the Indus Basin Irrigation System, or IBIS) is a network of thousands of kilometers of canals, distributaries, and narrow watercourses that spreads the flow of the Indus across vast areas of the provinces of Punjab and Sindh (Khan, 2009). The system is gravity fed, with flow allocation through the system dictated by slope, channel size, and geometry. Begun on the Ravi River (in what is now India) in 1886 (Bengali, 2009), the system has experienced more than a century of development, maintenance, depreciation, user manipulation, and changes in agricultural practice – current cropping intensities of 150% are more than double the design criteria for much of the system (Khan, 2009). Coupled with a lack of accounting for losses due to seepage, and to problems of poor drainage, the result is a build-up of inequitable access to surface water across the system's millions of users.

Considerable investment has been made by Pakistan and donors such as the World Bank in recent decades to address, among other issues beleaguering the system, the problem of inequity. Most notable has been the effort, now nearly two decades in process, of Irrigation Management Transfer (IMT), promoting a mode of participatory irrigation management that establishes a multi-tiered system of governance responsibility. At the level of the watercourse, from which individual farms draw water in a fixed-turn (*warabandi*) schedule, water user associations or *khal panchayat* (KP) are formed with the purpose of addressing watercourse level maintenance issues and conflicts. Khal panchayats elect a chairman who represents them in Farmers' Organizations (FOs), formed at the distributary level and holding responsibility for maintenance and conflict issues at the distributary level as well as for collection of water use fees (*abiana*) (Asrar-Ulhaq, 2010). Farmers' Organizations in turn send representatives to Area Water Boards (AWBs) formed for each canal command area. The progress of the reform and the performance of AWBs, FOs, and KPs has been well reviewed in recent literature (e.g., Ghumman et al., 2011; Latif & Tariq, 2009; World Bank, 2010) and we will not belabor this topic here, beyond summarizing that reform has yet been established in less than 1/5 of canal commands across Punjab and Sindh; and that performance issues of FOs across Sindh and Pakistan include yet-persistent inequity in water distribution and a low and declining willingness to pay *abiana* (Asrar-Ulhaq, 2010; Memon, 2006).

One ingredient in improving conditions across the basin may be information – monitoring and reporting of water availability through the irrigation system. Awareness of the higher-level constraints on water supply shaping availability in lower-level distributaries might provide some incremental improvement of willingness-to-pay, as the link between *abiana* and system maintenance is made more transparent; this in turn could facilitate the gradual scale up in cost recovery suggested by Briscoe et al. (2005). Additionally, disclosure of watercourse off-take volumes along distributaries may provide FOs with useful input to conflict resolution, and increase the cost of illegal manipulation of off-take.

In this study we begin inquiry into the potential value of information in the IBIS via an experimental game of water distribution played by farmers in Punjab province. This experiment is part of a larger project being undertaken jointly by IFPRI and IWMI that includes a pilot study of flow monitoring and reporting in the Hakra command area of Punjab. The broad goals of these efforts are to evaluate the potential impacts that improved information can have on farmer decisions and behavior, and thus on system-level efficiency and equity outcomes in the system.

Experimental approaches in Irrigation Systems

There are several salient examples in the literature of field and lab experiments using games in an irrigation context. D'Exelle et al. (2012) developed a paper-based 2-player game for members of small, self-governed irrigation systems in Tanzania. The structure of their game derives from the archetype of a repeated ultimatum game; the upstream player makes a decision on how many hours to keep his irrigation gate open (during which water capture is complete and no water flows downstream), and the downstream player is provided a mechanism to punish the upstream player for making inequitable choices. Production payoffs are an s-shaped, threshold function of hours of water used. Across treatments of water abundance and scarcity, the authors find preference for equity (as opposed to fear of punishment) as explaining well the patterns of water sharing and alternating water use under scarcity observed in the experiments.

In a series of experiments in the field and in the lab, another research effort led by Cardenas and Janssen has developed a computer-based irrigation game for 5 players that combines a public goods game with the upstream-downstream water distribution game (Cardenas, Janssen, & Bousquet, 2009; Janssen, Anderies, & Joshi, 2011). In this setup, players choose a resource contribution to make toward irrigation infrastructure maintenance; this captures the public-good nature of small, self-governed irrigation systems in which farmers reap benefits from their joint efforts in maintaining system performance. The total amount of water available for the round is a function of the total contribution from all players, which is then available to the players in a timed round during which the players extract water by opening and closing their irrigation gates. Players upstream have better access to water resources, creating a resource problem for downstream users if upstream gates are not left closed long enough for sufficient resources to travel to tail-end users downstream. The experiment adds the additional step of allowing players to choose a new governing rule (basing water access on a lottery, rotation, or water rights) after 10 rounds. The authors find lower social efficiency over repeated rounds as participants contribute less in the public goods games, but observe better distributions from upstream to downstream in the second half of their experiments, after players select their own rules for governance.

These examples share a common focus on small irrigation systems where contribution by members can lead clearly to improved outcomes, and where mechanisms exist for punishing abuse of the system over repeated rounds (such as by withholding contributions to maintenance). The realities in large-scale publicly-funded irrigation projects are different, as the linkages between contribution and outcome across the thousands of system participants are not as clear. In the current study we present results from a tablet-PC-based game implemented in the field that shares much in common with the works of D’Exelle et al., Janssen et al., and Cardenas et al., but that is tailored to the reality of the IBIS and thus differs in several key respects.

Firstly, our game does not include the public goods game of the Janssen and Cardenas groups. In the IBIS, farmers do pay water charges on a seasonal basis called *abiana* (Ghumman et al., 2011). Charged on a per-acre basis and varying by crop, these charges are collected by Farmers’ Organizations who retain a 40% share and pass the rest on to provincial revenue departments (Asrar-Ulhaq, 2010). The link back to maintenance of higher-order canals and distributaries is weak and not obvious to the contributing farmers, nor does the share retained locally contribute to a change in the availability of water made by the provincial irrigation department. Thus, the link between contribution and function highlighted by the Janssen and Cardenas games, and more broadly for self-governing irrigation systems by Ostrom (1992) is not a component of the massive IBIS.

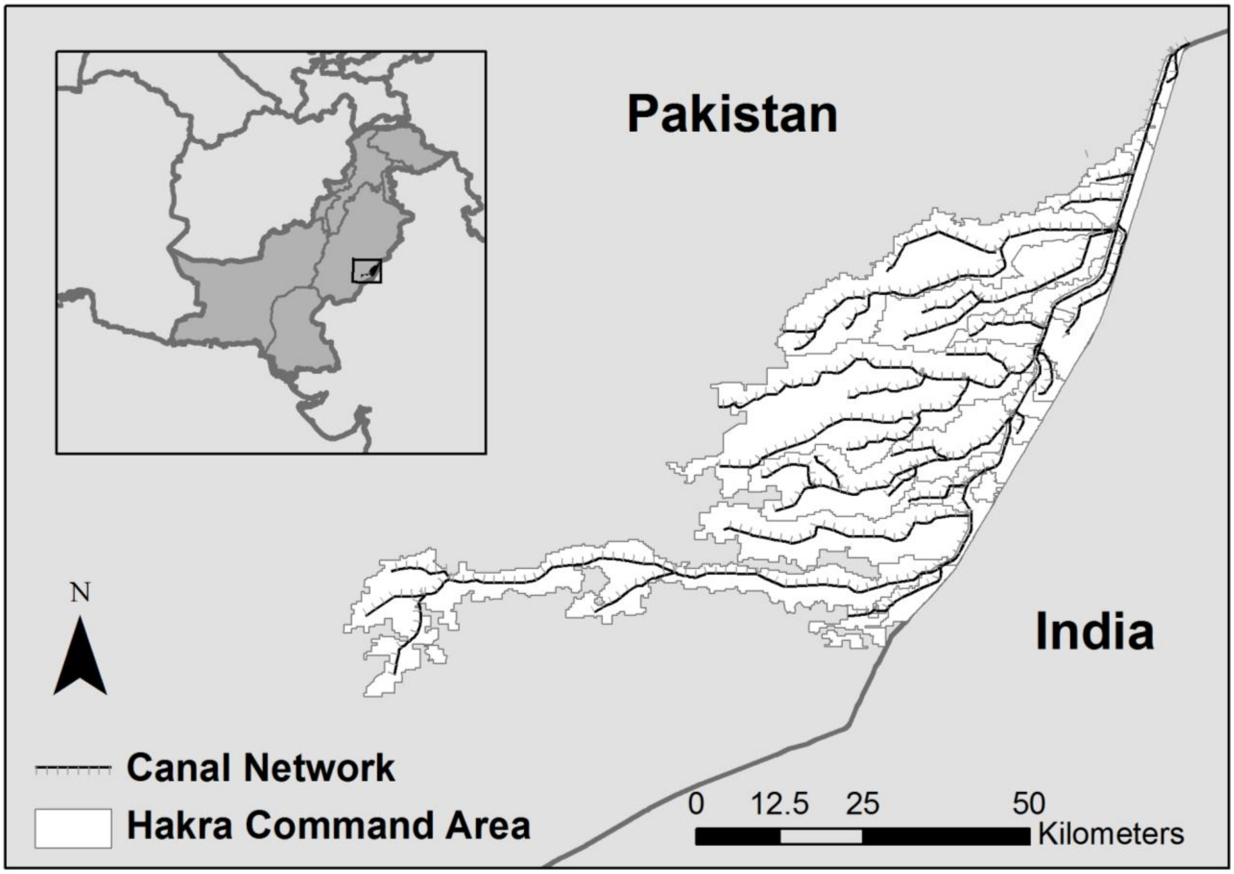
Secondly, while the experiments highlighted above focus on the time taken for water capture by participants, our experiment treats water received in each turn as a fixed quantity. While the IBIS does operate on a time-based fixed-turn system (called *warabandi*) of 7-10 day cycles, the usage of time within these cycles is not of primary interest in this study. The length of *warabandi* turns is calculated by a simple area-based formula, and though timing issues, unaccounted losses, and power dynamics lead to trading and significant deviations from this schedule (see for example Bandaragoda, 1998), these deviations do not vary much within a season. Rather than the issue of longer or shorter turns in a given week, we are interested in longer-term shifts in allocation, obtained by lobbying officials for a shift in official allocation (e.g., by a higher reported area in the official calculation) or by illegal physical manipulation of the gravity-fed system to increase flow to one’s property (thus reducing availability downstream). We thus treat a round of our game as a season, rather than a *warabandi* turn, and frame water off-take during the round as the cumulative water obtained over a season (with more water taken during a season leaving less water available downstream.

Study Area

The study area is located in the Hakra command area, between latitude 29º 3´ 35″ N to 29º 56´ 3″ N and longitude 72º 14´ 35″ E to 73º 26´ 17″ E (Map 1). The gross command area of Hakra Canal is 1.29 M.Acres, with a culturable command area of 1.04 M.Acres. The climate is hot and is characterized by large seasonal fluctuations in temperature and rainfall. June is the hottest month when the average maximum temperature over a period of fifteen years has been recorded as 45.9ºC. Temperature frequently exceeds 48.9ºC. Minimum temperature is observed in the month of January. The mean maximum and minimum temperatures during this month are 24.2ºC and 0ºC respectively. The average annual rainfall in this area is 59 mm/yr.

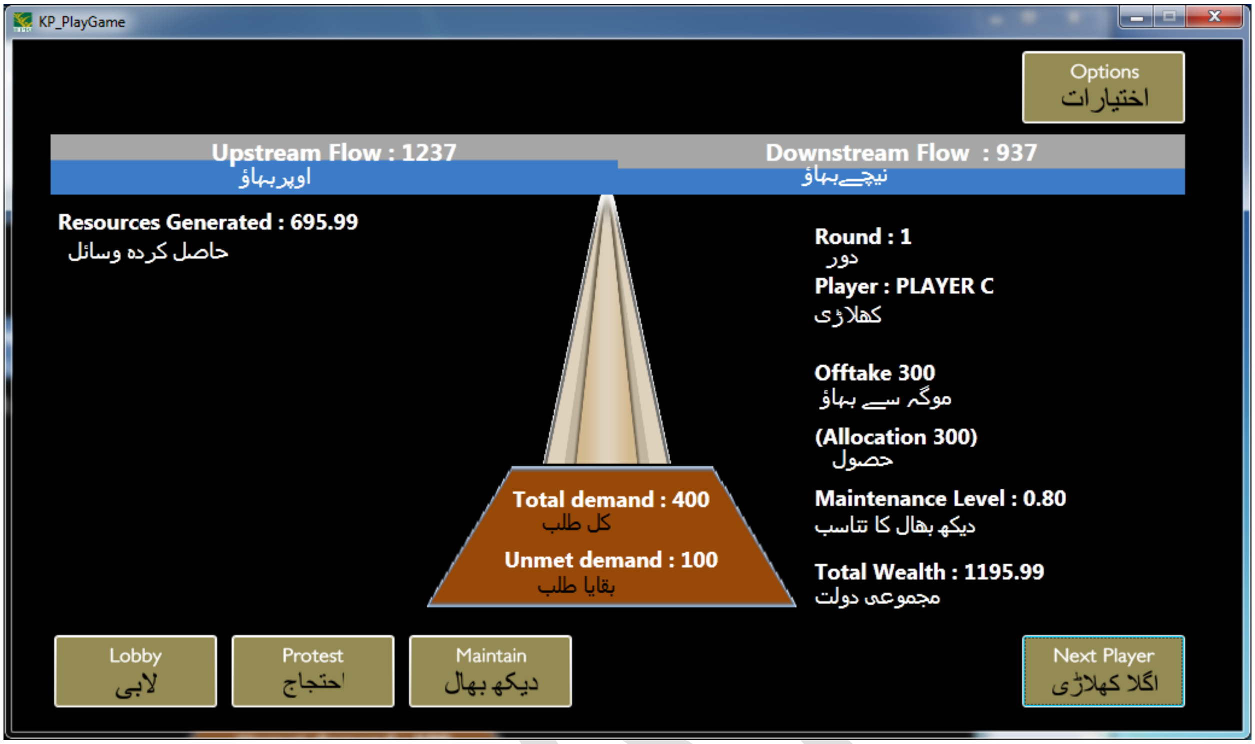
The water table in the project area ranges from less than 1 m to about 25 m. The major crops of the study area include wheat, cotton, sugarcane, fodder and rice. The crop yields are typically low in this area. Yields per hectare in tones are; for rice 1.6, cotton 1.3, wheat 1.9 and sugarcane 30. The cropping intensity is 129% on annual basis (Kharif = 55%, Rabi = 74%).

Hakra Branch Canal is part of the Area Water Board Bahawalnager Canal Circle (AWB BCC). It includes three canal divisions namely Fordwah, Sadiqia and Hakra. There are in total 69 functional FOs under this AWB of which 17 are included in the Hakra division.



Map 1 – Study Area

Methods



Upstream Flow : 1237
اوپربہاؤ

Downstream Flow : 937
نیچےبہاؤ

Resources Generated : 695.99
حاصل کردہ وسائل

Round : 1
دور

Player : PLAYER C
کھلاڑی

Offtake 300
موگہ سے بہاؤ

(Allocation 300)
حصول

Maintenance Level : 0.80
دیکھ بھال کا تناسب

Total Wealth : 1195.99
مجموعی دولت

Total demand : 400
کل طلب

Unmet demand : 100
بقایا طلب

Figure 1: Sample game screen shown to players in each round.

In our experiments groups of 6 players were randomly assigned positions from 1 (upstream, head end) to 6 (downstream, tail end). In each round of a game, players receive water, and allocate available resources in any amount among 3 available actions – maintenance, lobbying, and protest:

- **Maintenance** (increases the resource generation per unit of water available): In contrast to the public goods games cited above, here maintenance refers only to what is occurring within the player's individual productive area, and is not shared.

- **Lobbying** (increases a player's water allocation): Lobbying represents the investment of resources and effort into increasing one's own off-take – through any means – and is not framed to the participants as being an illegal activity.

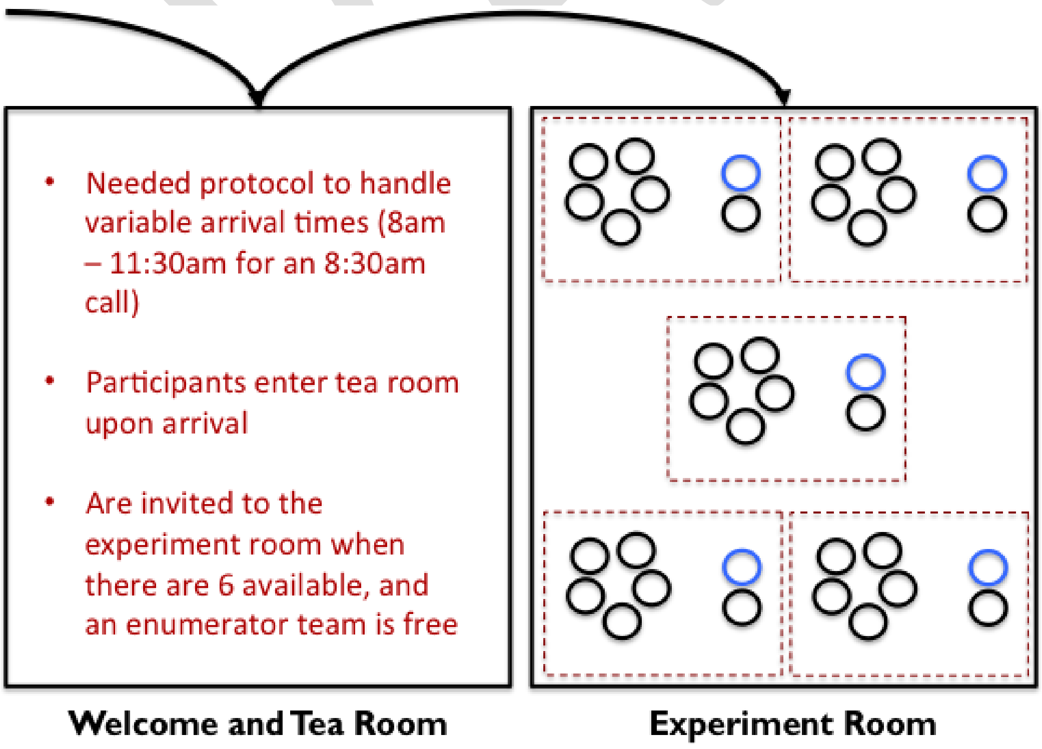
- **Protest** (decreases the allocation of a target player): Protest represents a mechanism (perhaps realized through KP and FO meetings) through which downstream users can invest their resources to challenge upstream water consumption (analogous to withholding contribution in the public goods game).

Players do not need to spend all of their resources, and may simply keep them for accumulation; in the experimental protocol, players are instructed to try to maximize the wealth accumulated over the course of the game. Water capture is not directly a choice for each player – as in the real IBIS, players have a fixed allocation of water, so that water receipt is equal to the lesser of the player’s allocated water, or the water remaining in the system. Resource generation in each turn is a logistic function of water received (as a fraction of total water demanded – held fixed and constant across all players) and maintenance level in the canal:

$$R = a_0 \cdot A \cdot \left(\frac{a_1 \cdot e^{a_2 \cdot (X-1)}}{1 + a_1 \cdot e^{a_2 \cdot (X-1)}} \right) \cdot \left(\frac{a_3 \cdot e^{a_4 \cdot (V-1)}}{1 + a_3 \cdot e^{a_4 \cdot (V-1)}} \right)$$

where X is the level of maintenance (ranging from 0 to 1) and V is the fraction of water demand being met (again, ranging from 0 to 1). The nature of this function is not revealed to the players, though the s-shape of the logistic curve is implied the participants in the training protocol, noting that as maintenance approaches 1 and as offtake approaches demand, additional investment will yield weaker marginal returns.

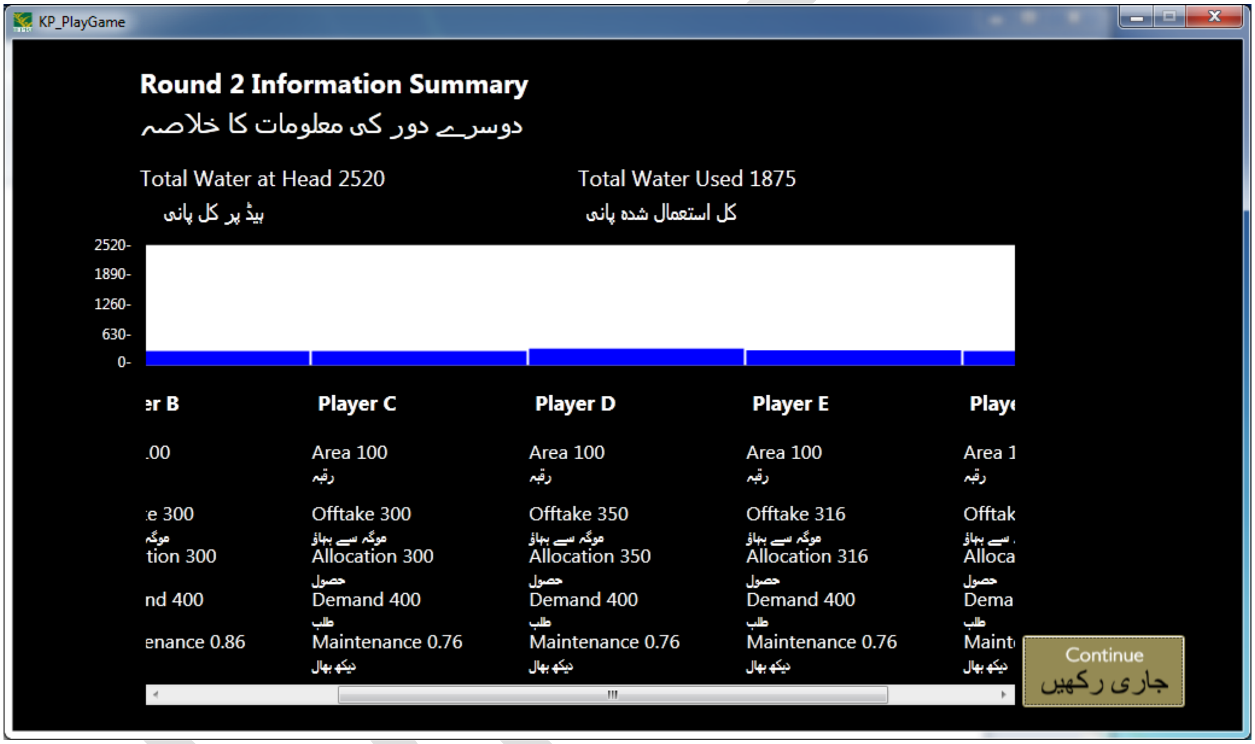
We randomly selected 300 farmers from lists provided by Farmers’ Organizations in the Hakra Branch command area, as well as a sample of 60 farmers listed as chairmen of their local Khal Panchayat (KP), for a total of 50 6-player game sessions played with farmers from our initial random sample, and 10 6-player game sessions played with our random sample of KP chairmen. Each game session consisted of a 4-round practice session, followed by two 6-round game treatments. In the first game treatment, players were not provided with any information about the decisions or off-take of other players in the game. Each player sat with an enumerator during their turn in a chair distanced from the other players (Figure 2), rejoining the other players after the turn was complete. Players were instructed not to discuss game actions while awaiting their turns, but were allowed to freely discuss any other issues they desired.



- Needed protocol to handle variable arrival times (8am – 11:30am for an 8:30am call)
- Participants enter tea room upon arrival
- Are invited to the experiment room when there are 6 available, and an enumerator team is free

Figure 2: Experimental setup. Farmers directed to welcome room upon arrival, and escorted by enumerators to experiment room when 6 players were available. Enumerator (blue circle) sat separately with current player during each turn.

In a second treatment, an information screen was shown to all players at the end of each round (Figure 3) indicating the allocation, off-take and demand of each player during the round. Enumerators explicitly noted what each value meant, and highlighted who had taken what during the round. In an ideal experiment, these treatments would each have taken place with separate groups (1 group, 1 treatment), but due to the rather finite population of farmers and KP chairmen in the area, this design was selected as a compromise that represented a plausible change between treatments (i.e., installation of flow monitoring and information infrastructure).



Round 2 Information Summary
دوسرے دور کی معلومات کا خلاصہ

Total Water at Head 2520
ہیڈ پر کل پانی

Total Water Used 1875
کل استعمال شدہ پانی

er B	Player C	Player D	Player E	Playe
.00	Area 100 رقبہ	Area 100 رقبہ	Area 100 رقبہ	Area 1 رقبہ
e 300 موگہ	Offtake 300 موگہ سے بہاؤ	Offtake 350 موگہ سے بہاؤ	Offtake 316 موگہ سے بہاؤ	Offtak سے بہاؤ
tion 300	Allocation 300 حصول	Allocation 350 حصول	Allocation 316 حصول	Alloca حصول
nd 400	Demand 400 طلب	Demand 400 طلب	Demand 400 طلب	Dema طلب
enance 0.86	Maintenance 0.76 دیکھ بھال	Maintenance 0.76 دیکھ بھال	Maintenance 0.76 دیکھ بھال	Maint دیکھ بھال

Figure 3: Between-round information screen from information treatment

Roundwise water availability varied along the 6 rounds, but was identical in both treatments (Figure 4). The available water as a fraction of total water demanded (the delivery performance ratio, or DPR) varied from nearly sufficient in rounds 1 and 2, to scarcity conditions in rounds 3 and 4 (during which water availability for the tail end players 5 and 6 was compromised) back to normal conditions in rounds 5 and 6. Costs for lobbying and maintenance were calibrated to yield approximately equal returns under the initial conditions of the game (Table 1), while costs for protests were held lower – such that downstream farmers not able to generate resources would still have access to the protest mechanism, but that the dominant strategy would not simply be for all players to simply protest against all others.

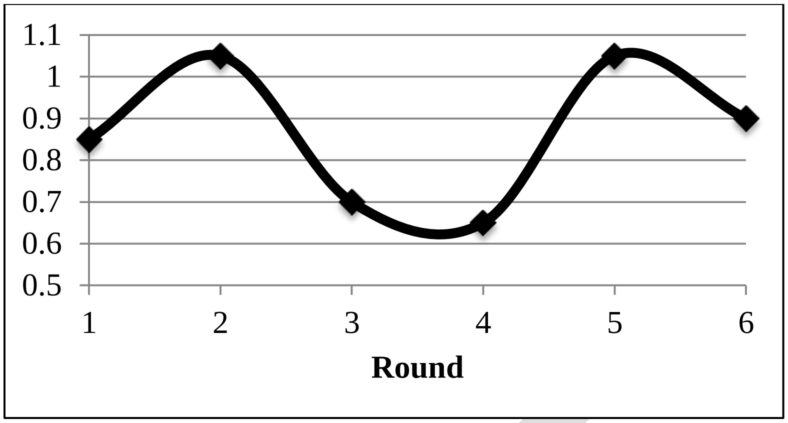


Figure 4: Round-wise Delivery Performance Ratio

Games were programmed in the .NET framework for Windows 7 and played on an HP Slate 2 tablet PC. The compiled application is available for download from XXXXXXXXX.

Table 1: Game parameter values

Parameter	Value
a0	60
a1	2
a2	6
a3	2
a4	6
Seepage Losses Between Players (% of total available water)	4
Lobbying Cost (per unit allocated)	15
Maintainance Cost (per 1% change per hectare of area)	0.6
Protest Cost (per unit allocated)	4
Initial Maintainance Level	0.7
Initial Capital	500
Water Demand (units)	400
Initial Allocation (units)	320
Maintenance decay (% per turn)	2

Results and Discussion

In a typical game, players invest in both maintenance and increased allocation throughout the game, leading to increased productivity on average across the system by the end of the 6th round. Protesting of water allocations is more pronounced by downstream players, but is by no means undertaken only by those not receiving their full allocation. Protesting of upstream players by those receiving their full allocations also occurs, as does (in a smaller number of cases) protesting of the allocations of downstream players by those upstream occurs as well.

Table 2: Game-level and player-level outcomes from 6th (final) round

	6th-Round Fraction of Water Demand Met			6th-round Resources Generated			End-of-Game Wealth		
	No Info	Info	P-value*	No Info	Info	P-value*	No Info	Info	P-value*
Game-level mean	0.80	0.80	0.28	1320.67	1351.66	0.57	2321.95	2265.44	0.75
Game-level between-player variance	0.06	0.07	0.38	604132.76	659166.22	0.39	3428047.58	3486286.12	0.76
Player 1 Mean	0.85	0.85	0.52	1435.51	1550.32	0.42	2678.22	2653.06	0.93
Player 2 Mean	0.85	0.85	0.89	1447.11	1453.04	0.98	2773.70	2721.58	0.77
Player 3 Mean	0.89	0.91	0.35	1708.13	1807.52	0.40	3339.34	3423.54	0.87
Player 4 Mean	0.91	0.90	0.80	1855.98	1721.49	0.51	3827.98	3322.57	0.16
Player 5 Mean	**0.88**	**0.92**	**0.04**	1232.00	1384.84	0.18	1111.25	1322.86	0.39
Player 6 Mean	0.42	0.39	0.69	245.31	192.74	0.61	201.21	149.01	0.57

*P-value from Mann-Whitney test

We look first to mean values (as a signal of efficiency) and variances (as a signal of equity) in watercourse-level outcomes (water received, resources generated, and overall wealth) between our no-information and information treatments, but do not find any significant differences (Table 2). This is not entirely surprising – the overall number of game outcomes is small, and the game-level outcomes result from a large number of controlled (game size, investment options, input water) and uncontrolled (player characteristics) variables. Importantly as well, in this experiment and in the real IBIS, shortages are experienced only in the tails, with upstream players having complete access to their allocated water. In our game, players 5 and 6 experience such shortages almost exclusively, so that analyses that differentiate outcomes by position along the watercourse are of greater interest.

Looking at the mean levels of water received and resources generated during the 6th round of each game (as a cumulative signal of in-game choices and outcomes), we find no strong signal of change across players 1 through 4 with the availability of information. We find a significant increase ($\alpha = 0.05$) in the 6th-round amount of water received by player 5 under the information treatment, and a weakly significant increase ($\alpha = 0.2$) in the 6th-round level of resources generated by player 5; we find a drop in both outcomes for player 6, though this is not significant. While it remains important to keep the small size of our experiment in mind in interpreting these results, they have a clear interpretation in the context of irrigation systems. Namely, that on average, information on water allocation and receipt allowed the players in positions 5 and 6 in our game (i.e., those affected by scarcity) to better target protests against upstream players, significantly increasing the reach of water resources toward the tail end of the watercourse. However, those benefits are shared unequally by players 5 and 6, with only player 5 reaping significant production improvements.

We can get further insight into protesting as well as lobbying behavior by looking both at the overall volumes of these actions by turn and by player across each treatment, and as well at how well they were targeted (Tables 3-5). That is to say, in the case of protesting, we can examine the average water receipt in turn *i* of the targets of protest in turn *i*+1, weighted by the amount of protest against them in turn *i*+1 (players learn of round *i* water receipts before making round *i*+1 decisions in the information treatment), averaging by 'protestee' (Table 3) or by protester (Table 4). These two analyses answer the questions "How much water on average was received by protest targets in position X in turn Y?" and "How much water on average was received by the targets of protests from the player in position X in turn Y?" respectively. In a similar way for lobbying, we can examine the average water receipt in turn *i* of those who lobby for increased allocations, weighted by the amount they lobby in turn *i* (players make lobbying decisions in turn *i* after observing what they receive in turn *i*) (Table 5). This analysis provides insight to the question "How much water on average was received by players lobbying for increased allocation in position X in turn Y?"

A casual look at these three tables reveals results that fit easily with intuition – protests more frequently and strongly come from downstream players, and target upstream players; lobbying activity is strong across most players, but weakens among those tail end players who do not receive water close to their allocation. These patterns give confidence that the functions of these activities were well understood by game participants. Looking in more depth at the differences between the no-information and information treatments, there are several results worth highlighting.

First, the protest-weighted average water receipt by turn and position, averaged by protestee does not appear to be significantly improved by information (significant results here would imply that a particular position, in a particular turn, was being protested against more strongly due to increased water receipt in the information treatment than in the no-information treatment). There is of course an endogeneity issue here – effective protesting would lead to lower levels of water receipt – so that this particular measure may not be of interest.

Looking instead at the protest-weighted average water receipt, averaged by protester (where significant results imply that a particular position, in a particular turn, targeted other players more strongly based on their water receipts in the information treatment than in the no-information treatment), we have another lens into the actions of the players in position 5 mentioned earlier. Protests by player 5 in rounds 1 and 2 are significantly better targeted under information ($\alpha = 0.1, 0.01$, respectively). Complementing this, lobbying efforts by player 5 in rounds 5 and 6 are made at significantly higher levels of water receipt – that is to say, on average player 5 is in an improved position to lobby for more water under the information treatment.

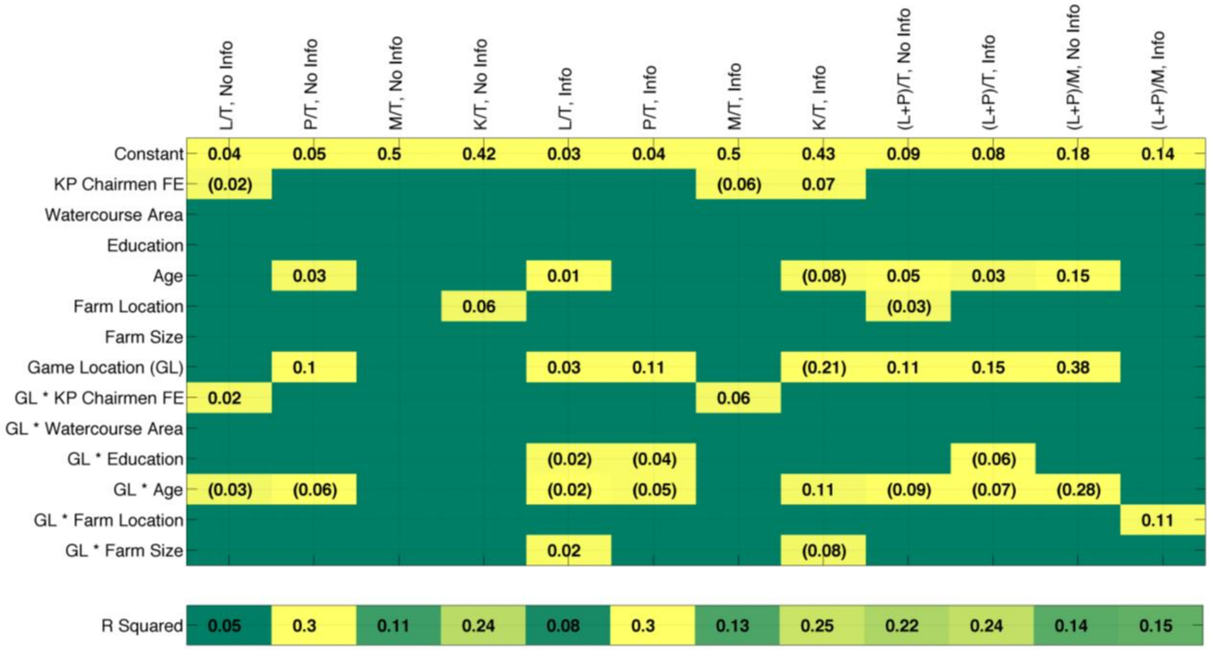
The lobby-weighted average water receipt results (where a significant result implies that lobbying activities in a particular position and turn are motivated by a different level of water receipt in the two different treatments) show little significant difference between treatments other than for player 5. As before, this must be taken in the context of a noisy outcome within a small study. However, the implication is that knowledge of insufficient access to water downstream did not change upstream lobbying activities for greater water access. Coupled with the overall lower instance of protest from upstream positions, this highlights the idea that information on water availability by itself appears to be consumed mainly by downstream users.

Having noted the differences in protest and lobbying behavior that occur across games and positions, we wish to examine whether these behaviors can be explained to any extent by characteristics of the players themselves – that is, do characteristics such as age, education, or the position of one's own property have bearing on how one plays the game? We consider the main decisions in the game to be the amount spent on lobbying (L), the amount spent on protesting (P), the amount spent on maintenance (M), and the amount simply kept without being used (K), and we evaluate how well variation in these decisions can be explained by factors outside of gameplay. That is, we do not regress against in-game variables such as the amount of water being received or allocated; we do however control for the position in game, or 'game location' (GL) and build interaction terms on GL, since our previous analysis demonstrated key differences in play depending on in-game position.

Overall, we have better ability to explain P and K (how much players protest or save) with such out-of-game characteristics, and relatively poor explanation for M and L (how much players maintain or lobby), across both information and no-information treatments (Figure 5). While a number of characteristics seem to have a role in explaining some small number of our constructed dependent variables (e.g., games played among KP chairmen exhibit lower levels of lobbying when there is no information, and lower levels of maintenance when there is information), many of these effects (or their lack of consistent effect) have little obvious mechanistic explanation. There is however one set of relationships that appears consistent across a range of dependent outcomes – greater age and lower game location (GL) appear to explain higher levels of lobbying or protesting behavior, and lower levels of retained wealth. The interaction of the two variables is significant across many of the regressions as well with the opposite sign, suggesting that the two substitute for one another against the boundaries of resources available within the game. Put very broadly, these results suggest the relationship:

$$Spending\ on\ Lobby\ or\ Protest \sim \beta_1 \cdot Age + \beta_2 \cdot GL - \beta_3 \cdot Age \cdot GL$$

Plainly speaking, older players appear more likely to push for increased allocations or protest the allocations of others. Players placed at the tail end are more likely to do the same, although this appears to be related to the game context only – actually living as a tail ender does not appear to have significant influence on such behavior in the game (Figure 5). This strong effect of age on behavior in the game suggests that hierarchy within groups of farmers may matter, though other indicators of status such as education or farm size did not appear to have broad explanatory power in this analysis.



	L/T, No Info	P/T, No Info	M/T, No Info	K/T, No Info	L/T, Info	P/T, Info	M/T, Info	K/T, Info	(L+P)/T, No Info	(L+P)/T, Info	(L+P)/M, No Info	(L+P)/M, Info
Constant	0.04	0.05	0.5	0.42	0.03	0.04	0.5	0.43	0.09	0.08	0.18	0.14
KP Chairmen FE	(0.02)						(0.06)	0.07				
Watercourse Area												
Education												
Age		0.03			0.01			(0.08)	0.05	0.03	0.15	
Farm Location				0.06					(0.03)			
Farm Size												
Game Location (GL)		0.1			0.03	0.11		(0.21)	0.11	0.15	0.38	
GL * KP Chairmen FE	0.02						0.06					
GL * Watercourse Area												
GL * Education					(0.02)	(0.04)				(0.06)		
GL * Age	(0.03)	(0.06)			(0.02)	(0.05)		0.11	(0.09)	(0.07)	(0.28)	
GL * Farm Location												0.11
GL * Farm Size					0.02			(0.08)				
R Squared	0.05	0.3	0.11	0.24	0.08	0.3	0.13	0.25	0.22	0.24	0.14	0.15

Figure 5: Highlighted regression outcomes. Columns display dependent variables, regressed individually against set of independent variables shown in rows. Cells highlighted in yellow are significant at α = 0.05; numbers in yellow cells indicate regression coefficients, with negative coefficients enclosed in parentheses. Full regression table included as appendix

Implications

Before discussing the implications of these results, it is important to emphasize the limitations of the experiment and the game context. First, as has been highlighted already, this study drew on a relatively small sample due to limits of time and population, reflecting the challenges of a game context where 6 participants produce only one game-level data point. Second, the nature of the field setup limits the length of games that can be played. In the experimental setup of Janssen et al., the networked computers and simultaneous play of timed rounds allowed for 20 rounds of play to be incorporated into the experiment in fairly short time. In our setup, with players participating serially, a game session of two 6-round games plus training and practice consumed nearly 3 hours, making it difficult to lengthen the games (allowing greater opportunity for behavioral patterns to emerge). Third, our game included a scarcity signal that had impacts only for the tail-enders in the game. Though this may better reflect realities of watercourses in the IBIS, a stronger scarcity signal may have had the effect of inducing stronger behavioral signals and differences in game-level outcomes between our no-information and information treatments.

Finally, and perhaps most importantly, it is important to note that the experimental game context may not capture the conditions of the real irrigation system that motivate strategic behavior, nor engage the same thinking processes.

With these caveats stated, there are several results highlighting in the summary of our findings. First, the result that upstream players (whose water supply was unaffected by scarcity) did not change their behavior in response to information that downstream players were not receiving adequate water. It is not necessarily surprising that the equitable outcomes observed in the games of D'Exelle et al. or Cardenas et al. did not occur in the current study. In smallholder irrigation systems, infrastructure is a shared public good, providing an opportunity for tail-enders to punish through non-contribution to maintenance. However, this mechanism does not exist in the same way in large public systems like the Indus. We provided an analogous punishment mechanism to other games by allowing protest by downstream players, acting to reduce upstream allocations, upon which downstream players relied heavily (Tables 3-5). However, while access to information allowed these protests to be targeted more effectively by downstream players, they did little to change behavior of upstream players, highlighting the key role that the public good nature of small irrigation systems plays in shaping performance outcomes.

As a further qualifier on this difference, we observed that while tail-enders were able to improve their conditions through protest and more so with access to information, these improvements were not shared across the tail end. The efforts of players in positions 5 and 6 in our game led to improved availability of water, consumed entirely by player 5. While this provides some evidence of the practical value of information access, it is a reminder that information alone may not necessarily address the needs of those who are in greatest need. Institutional development (such as by effective financing of KP and FO activities, to start) may be a mechanism through which to make better use of such information and develop the ethos of shared access observed in D'Exelle et al.'s Tanzanian experiments.

We note that the level of lobbying and protest is explained in significant part by the age of the game players, controlling for the position played in the game. This is perhaps a reminder of the ways that existing hierarchy and power dynamics can shape outcomes in any group process (such as a group game, or perhaps a water users association meeting). If this result has any bearing on group dynamics in real irrigation activities, then it suggests the importance of encouraging members of all age groups to speak out freely, as a means of moving toward equitable outcomes.

This experiment represents, as initially stated, a first step in our inquiry of how access to information can shape irrigation outcomes. Our next effort will be to implement a pilot study of flow monitoring and reporting in a distributary in the Hakra command and observe production and equity outcomes over the period of several seasons. Together we hope these efforts will inform the value of investment in information for large irrigation systems such as in Pakistan's Indus Basin.

Literature Cited

Asrar-Ulhaq. (2010). PERFORMANCE OF FARMERS ' ORGANIZATIONS IN PUNJAB , PAKISTAN : THE CHALLENGES AND WAY FORWARD. *Irrigation and Drainage*, *59*, 23–30. doi:10.1002/ird.547

Bandaragoda, D. J. (1998). *Design and Practice of Water Allocation Rules : Lessons from Warabandi in Pakistan ' s Punjab*. *Management* (p. 34). Colombo, Sri Lanka.

Bengali, K. (2009). Water Management Under Constraint: The Need for a Paradigm Shift. In M. Kugelman & R. Hathaway (Eds.), *Running on Empty: Pakistan's Water Crisis* (pp. 45–63). Washington, DC: Woodrow Wilson International Center for Scholars.

Briscoe, J., & Qamar, U. (2005). *Pakistan's Water Economy: Running Dry* (p. 155). Washington, DC: World Bank.

Cardenas, J., Janssen, M., & Bousquet, F. (2009). Dynamics of Rules and Resources : Three New Field Experiments on Water , Forests and Fisheries " 1. In J. List (Ed.), *Handbook on Experimental Economics and the Environment* (pp. 1–27). Edward Elgar Publishing.

D'Exelle, B., Lecoutere, E., & Van Campenhout, B. (2012). Equity-Efficiency Trade-Offs in Irrigation Water Sharing: Evidence from a Field Lab in Rural Tanzania. *World Development*, *40*(12), 2537–2551. doi:10.1016/j.worlddev.2012.05.026

Ghumman, A. R., Khan, R. A., Hashmi, H. N., Kamal, M. A., & Khan, I. T. (2011). Performance assessment of canal irrigation in Pakistan. *African Journal of Agricultural Research*, *6*(12), 2692–2698.

Janssen, M. a., Anderies, J. M., & Joshi, S. R. (2011). Coordination and cooperation in asymmetric commons dilemmas. *Experimental Economics*, *14*(4), 547–566. doi:10.1007/s10683-011-9281-9

Khan, F. (2009). Water, Governance, and Corruption in Pakistan. In M. Kugelman & R. Hathaway (Eds.), *Running on Empty: Pakistan's Water Crisis1* (pp. 82–104). Washington, DC: Woodrow Wilson International Center for Scholars.

Latif, M., & Tariq, J. A. (2009). PERFORMANCE ASSESSMENT OF IRRIGATION MANAGEMENT TRANSFER FROM GOVERNMENT-MANAGED TO FARMER-MANAGED IRRIGATION SYSTEM : A CASE STUDY y. *Irrigation and Drainage*, *286*(July 2008), 275–286. doi:10.1002/ird

Memon, N. A. (2006). Participatory Irrigation Management and Institutionalizing Irrigation Service in Sindh. *Proceedings of the INPIM's Ninth International Seminar on Participatory Irrigation Management* (pp. 71–84). Lahore, Pakistan.

Ostrom, E. (1992). *Crafting institutions for self-governing irrigation systems* (p. 111). San Francisco: Institute for Contemporary Studies.

World Bank. (2010). *Implementation Completion and Results Report on the Sector Development Policy Loans in the amount of JP¥11,780,000,000 (US$ 100 Million Equivalent) and in the amount of US$ 100 Million to the Islamic Republic of Pakistan for Punjab Irrigation Sector Devel* (p. 69). Washington, DC.

Table 3: Protest count and statistics, averaged by protest recipient ‘protestee’

		No information Treatment						Information Treatment					
		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**	**Player 1**	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
Total Resources Lobbied	*Round 1*	0	0	0	0	0	0	0	0	0	0	0	0
	Round 2	537	254	260	81	109	66	470	353	245	120	71	25
	Round 3	1234	1408	1002	559	190	17	1005	977	860	510	111	24
	Round 4	889	788	469	389	108	12	1246	916	672	479	49	0
	Round 5	569	574	461	245	102	15	613	759	254	341	116	0
	Round 6	723	647	425	279	197	25	721	731	486	396	250	0

		No information Treatment						Information Treatment					
		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**	**Player 1**	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
Total Lobbying Events	*Round 1*	0	0	0	0	0	0	0	0	0	0	0	0
	Round 2	20	14	12	4	5	2	24	19	17	8	5	1
	Round 3	45	46	38	30	12	1	40	42	36	24	6	2
	Round 4	38	32	29	19	10	1	38	34	30	27	4	0
	Round 5	28	28	26	16	7	1	25	26	16	13	6	0
	Round 6	35	28	24	14	8	1	28	30	25	21	11	0

		No information Treatment						Information Treatment					
		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**	**Player 1**	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
Protest-weighted Water Receipt	*Round 1*	0	0	0	0	0	0	0	0	0	0	0	0
	Round 2	320	320	320	320	320	245	320	320	320	320	320	245
	Round 3	322	325	325	329	330	320	332	328	335	339	350	323
	Round 4	328	338	331	349	261	0	336	337	343	350	263	NaN
	Round 5	333	324	336	349	121	0	329	338	341	360	73	NaN
	Round 6	335	321	344	387	320	303	350	328	350	355	372	NaN

		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
P-value of difference of weighted mean water receipt	*Round 1*	0	0	0	0	0	0
	Round 2	NaN	NaN	NaN	NaN	NaN	NaN
	Round 3	0.08	0.28	0.04	0.08	0.10	NaN
	Round 4	0.22	0.54	0.11	0.46	0.48	NaN
	Round 5	0.59	0.18	0.35	0.23	0.78	NaN
	Round 6	0.14	0.34	0.36	0.99	0.00	NaN

NaN - Not a Number - comparison not possible due to low n or invariance

Table 4: Protest count and statistics, averaged by protest sender ‘protester’

No information Treatment

		Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Total Resources Lobbied	*Round 1*	0	0	0	0	0	0
	Round 2	133	79	126	55	260	654
	Round 3	138	50	363	282	1970	1607
	Round 4	104	75	106	317	1360	693
	Round 5	13	13	232	109	672	927
	Round 6	57	51	137	125	666	1260

		Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Total Lobbying Events	*Round 1*	0	0	0	0	0	0
	Round 2	5	2	6	5	19	27
	Round 3	8	1	12	8	128	116
	Round 4	9	1	3	22	88	59
	Round 5	1	1	14	6	44	69
	Round 6	2	1	8	5	29	84

		Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Protest-weighted Water Receipt	*Round 1*	0	0	0	0	0	0
	Round 2	340	331	332	347	332	343
	Round 3	340	370	354	337	343	344.4045
	Round 4	346	339	349	387	350	347.2496
	Round 5	353	247	301	331	364	377
	Round 6	388	267	355	320	368	359

		Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
P-value of difference of weighted mean water receipt	*Round 1*	0	0	0	0	0	0
	Round 2	NaN	0.97	0.37	0.41	0.06	0.08
	Round 3	NaN	NaN	0.20	0.09	**0.00**	0.13
	Round 4	0.37	NaN	0.27	0.31	0.78	0.93461
	Round 5	NaN	NaN	**0.00**	0.61	0.28	0.83
	Round 6	0.37	NaN	0.34	0.35	0.72	0.07

Information Treatment

	Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Round 1	0	0	0	0	0	0
Round 2	0	49	162	178	256	639
Round 3	0	151	57	198	1324	1757
Round 4	35	109	166	756	1321	975
Round 5	41	73	90	320	539	1020
Round 6	177	108	328	205	351	1415

	Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Round 1	0	0	0	0	0	0
Round 2	0	2	9	8	21	48
Round 3	0	5	3	11	86	112
Round 4	2	7	8	28	91	64
Round 5	2	4	5	16	27	66
Round 6	5	7	12	9	21	95

	Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Round 1	0	0	0	0	0	0
Round 2	NaN	326	337	351	341	349
Round 3	NaN	334	373	360	355	349
Round 4	354	392	365	392	346	336.7446
Round 5	400	371	398	321	371	369
Round 6	394	386	367	335	357	369

NaN - Not a Number - comparison not possible due to low n or invariance

Table 3: Lobby count and statistics, averaged by lobbying player

		No information Treatment							**Information Treatment**					
		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**		**Player 1**	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
Total Resources Lobbied	*Round 1*	950	1176	1089	1108	1201	378	*Round 1*	1275	1224	1132	1281	1269	474
	Round 2	1070	970	909	1072	1051	939	*Round 2*	1086	1101	892	934	851	791
	Round 3	1109	799	1011	718	128	19	*Round 3*	887	873	896	634	303	29
	Round 4	1095	1073	1135	834	70	0	*Round 4*	1248	970	918	762	177	1
	Round 5	830	922	651	578	428	573	*Round 5*	1023	930	895	559	600	563
	Round 6	1030	984	751	721	715	266	*Round 6*	1168	938	665	539	452	131

		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**		**Player 1**	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
Total Lobbying Events	*Round 1*	41	43	42	44	42	20	*Round 1*	46	49	43	42	46	23
	Round 2	45	40	42	44	45	41	*Round 2*	47	44	43	42	44	41
	Round 3	43	41	41	37	13	2	*Round 3*	43	42	45	33	23	4
	Round 4	43	42	41	39	8	0	*Round 4*	44	44	39	31	11	1
	Round 5	39	40	31	31	26	28	*Round 5*	41	42	38	30	33	28
	Round 6	37	40	38	28	31	12	*Round 6*	37	39	33	23	28	12

		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**		**Player 1**	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
Lobby-weighted Water Receipt	*Round 1*	320	320	320	320	320	245	*Round 1*	320	320	320	320	320	245
	Round 2	327	334	335	335	343	329	*Round 2*	327	328	341	338	341	328
	Round 3	338	341	338	351	210	0	*Round 3*	340	340	342	349	235	28
	Round 4	333	321	337	329	182	NaN	*Round 4*	330	341	335	335	203	0
	Round 5	335	323	347	364	348	336	*Round 5*	316	326	338	351	365	339
	Round 6	346	333	349	377	346	259	*Round 6*	348	321	351	336	365	284

		Player 1	**Player 2**	**Player 3**	**Player 4**	**Player 5**	**Player 6**
P-value of difference of weighted mean water receipt	*Round 1*	NaN	NaN	NaN	NaN	NaN	NaN
	Round 2	0.51	0.86	0.10	0.28	0.66	0.64
	Round 3	0.37	0.58	0.26	0.62	0.20	0.14
	Round 4	0.61	**0.01**	0.62	0.23	0.33	NaN
	Round 5	0.93	0.40	0.80	0.85	**0.01**	0.28
	Round 6	0.42	0.87	0.41	1.00	**0.01**	0.25

NaN - Not a Number - comparison not possible due to low n or invariance