The Value of Decentralized Decision-Making: Lessons from an Agricultural Infrastructure Experiment

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Abstract

Collective action problems loom large in the choice and construction of commonly-owned infrastructure, suggesting the need for external intervention. We find experimental evidence in support of significant barriers to collective action in the context of surface irrigation field channels. Across 240 villages in Telangana (India), we randomize whether or not a village receives a field channel construction intervention or receives a budget-equivalent untied cash grant made to each constituent farmer. We find that only 20% of the cash grant villages constructed any field channel as opposed to 100% among the intervention villages. Further, the constructed channels substantially increase irrigation by 40 days (a 45% increase) and reduce labor costs by 10%. To identify an optimal institutional design to facilitate channel construction, we use a 2-by-2 design where we experimentally vary two aspects: (a) the choice of channel location which contrasts a one-person-one-vote referendum to a social planner's benchmark based on private elicitation, and (b) implementation of the channel construction that compares construction by local community members to that by an external third-party

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contractor. We find that the referendum did not lead to the socially optimal location of the channel in the majority of cases and results in lower irrigation by 10 days (25%) among those receiving the channel intervention. Moreover, the referendum generates a regressive distribution of irrigation resources towards more elite farmers. Taken together, these findings suggest that the social planner benchmark with private information outperforms the more participatory alternatives considered in overcoming coordination problems.

1 Introduction

Responding to the consequences of externalities, such as those arising from commonly-owned infrastructure, requires collective action and coordination between multiple stakeholders. On the one hand, standard textbook solutions to overcoming such externalities include common ownership or centralized provision. On the other hand, local communities may have divergent preferences and ultimately bear the cost. Given this tension, what is the best way to give agency to local communities in designing infrastructure projects? And, what are the costs of participation? These are open questions and the literature on decentralization is unclear about when and why decentralization generates socially optimum outcomes (Hayek, 1945; Mookherjee, 2015).[1]

In this paper, we present experimental evidence of different degrees of community involvement on the social optimality of an infrastructure project choice, quality of project implementation, ongoing maintenance, and economic productivity in a context where preferences over the project - irrigation infrastructure - are well defined and can be elicited ex-ante (resolving the information problem central in Hayek 1945). The specific infrastructure project we examine is the construction of field channels linking local irrigation reservoirs (tanks) to agricultural plots in the downstream command area (ayacut) in 240 villages in Telangana, India, using a randomized controlled trial design. Channel construction requires collective action among farmers in the ayacut, where farmers face threats of free-riding behavior and require cooperation from other farmers who need to allow water to pass downstream.

At baseline, we collected rich data on irrigation availability, agricultural productivity and costs, and willingness to pay for each feasible location of irrigation channels among a representative sample of over 6200 constituent farmers. We find that around 45% of the irrigation channels in the study ayacuts were under disrepair and not in use, but many farmers would have derived large positive values through additional revenue if these channels were functional. This begs the question whether centralization would solve this coordination problem. Alternatively, this could reflect credit constraints, where even though some farmers derived

[1] For example, centralized provision of infrastructure such as roads, irrigation canals, etc., can affect local communities in both positive and negative ways. On the other extreme, a decentralized approach requiring community members to participate in programs to identify locally suited strategies may incur substantial time costs in participating in such programs, often providing voluntary time and labor contributions. In communities with a significant number of poor, such costs impose a regressive tax.

positive value, they are unable to smooth consumption and face constraints in paying the cost of construction upfront.

Further, proponents of local agency emphasize including communities in development projects. Their argument includes instrumental and intrinsic values of decentralization and democracy (Bardhan and Mookherjee 2006; Dal Bó et al. 2010; Ostrom 1990), with instrumental value from better information on local preferences and improved monitoring of funds (Chambers 1984; Oates 1999, 1972), and intrinsic value from empowering the communities and strengthening their capacity for program implementation (Dal Bó et al. 2010; Ostrom and Gardner 1993). Despite the lack of robust evidence for or against the role of community in development programs (Casey 2018; Mansuri and Rao 2004, 2013; Qian 2015; Wong and Guggenheim 2018), participatory development or CDD has become a central strategy for governments and international agencies over the past few decades. The World Bank alone supports more than 199 active participatory projects in 78 countries valued at USD 19.7 billion, constituting a sizeable fraction of its lending portfolio.

To shed light on these opposing theories, we create experimental variation along 3 dimensions. First, we examine whether or not there exists a collective action problem by comparing an infrastructure selection and construction intervention with a cost-equivalent budgetary support intervention (budget-neutral control). We randomize 1962 of 240 villages to get the infrastructure program (choosing and constructing an irrigation channel) and the remaining 48 villages to get cost-equivalent of the irrigation program as untied funds transfer, where we distribute the program cost among constituent farmers. Second, we test whether giving community agency over choosing the location of the project matters via a one-farmer-one-vote ballot referendum initiative. We compare this with a design where the location is selected based on maximization of social welfare using privately elicited willingness to pay from baseline, without giving a direct agency to the local community in the act of choosing. Third, we vary community agency over project implementation, where we either have the community constructing the selected channel on their own or construct ourselves using third party contractors. We cross-randomize both choice and implementation dimensions to get 4 additional experimental variations in institutional design, with varying degree of community agency over choice and implementation, generating a sample of 48 villages randomly assigned to each of the program intervention groups. To enable accurate comparisons, we ensure that all experimental arms are budget-neutral. We stratify the randomization at a higher-level geographic aggregation (district), each of which have distinct agro-climatic conditions and aquifer hydro-geology, to improve precision and statistical power.

There are four main results. First, we note a strong first stage - channel construction follows the design of the respective intervention. In particular, fewer number of channels were constructed in the budget-neutral control group - only 6 control villages reported constructing one or more channels - compared to 100% in all of the four intervention arms (i.e., 192 field irrigation channels were built as a result of this program). Consequently, farmers report substantially more days of surface irrigation relative to the budget-neutral group. The increase in irrigation is a staggering 40 additional days relative to 100 days in the control group on average. The increase in access to irrigation is mainly driven by the constructed channel, which also directly abuts about 40% of all plots within the ayacut. This increase in the quantum of surface irrigation persists over 3 agricultural seasons from the time of construction.[2]

Second, we record substantial differences in the outcomes by choice groups but nothing significant when we vary how the construction is implemented. We find that the channel selected via referendum is different from the social optimal in over half of the referendum villages. If the referendum captured the private willingness to pay accurately, the outcome would have been the same across both choice/no-choice groups. This divergence could be plausibly due to relatively high costs of participation: very few farmers directly participate by turning up to vote. Surprisingly, even those that cast their ballot voted a channel different from what they preferred in private, suggesting that participation costs alone does not explain the difference and that there is likely strategic behavior on part of the voters. Consequently, ballot villages get fewer days of surface irrigation relative to the social planner benchmark. Once a channel is selected, it does not really matter how it's construction is implemented for subsequent water allocation. But construction timeline is a little longer and we note minor deviations in the design of the channel (for example, whether it is straight reaching the tail-end or meandering) when channels are constructed by the local communities.

Third, the referendum intervention generates regressive water allocation patterns relative to the social planner benchmark in addition to a reduction in the average number of days of surface irrigation. Specifically, farmers with plots in the head-end (closest to the reservoir and thus, with first user rights), plots with functioning wells, and large land area plots report more surface irrigation in ballot villages relative to their counterparts in the social planner group. These farmers reported lower value from an additional day of irrigation at baseline. The distribution patterns are also consistent with whose choice gets reflected in the outcome of the referendum - head-end and large landholders are more likely to turnout and vote their privately optimal channel and also are more likely to get their choice of channel constructed.

Fourth, we find that access to irrigation lowers the distribution of the cost of production, particularly labor costs, by shifting it to the left across all intervention groups relative to the budget-neutral control group. This is because the main crop cultivated within these command areas is paddy, which is labor intensive for weeding. However, with greater access to cheaper surface irrigation, farmers keep their fields flooded to lower weed growth, reducing the need for weeding labor. Correspondingly, we also note lowering of agricultural wages for female

[2]This corresponds to 1.5 calendar years following the construction of the channel.

labor who are mainly engaged in weeding.

Viewing the results together suggests that having information on all individuals' private willingness to pay is important to determine the social optimality of the channel location, which enables marginalized communities to adapt to the vagaries of climate and weather shocks through irrigated agriculture. We infer that encouraging community participation is not a silver bullet and that the mode of giving agency to communities in the selection of location matters. Further, giving budgetary support alone is insufficient to overcome coordination failure in creating and maintaining field irrigation channels. Importantly, the communities benefit from external facilitation either through bottom-up implementation or through a third party top-down implementation. We find that it does not really matter who gets involved in the actual construction process (i.e., whether local communities themselves as in bottom up or contractors as in top-down), at least over the time scale of this study. At the same time, external facilitation reduces the cost of participation across all intervention groups relative to the budget-neutral control.[3]

We take a number of precautions in implementing the research design. First, we registered the entire pre-analysis plan before we executed any of the experimental interventions. Second, we implemented a strong data quality control protocol, where we went back to 25% of the respondents using different enumerator teams to collect some of the variables to test for any reporting errors. We did not find any substantial misreporting. Third, we triangulate our results based on survey reported data through random site visits and measurement based on visual inspections and GPS technology.

This paper makes several contributions. First, we provide experimental evidence on the presence of collective action and coordination frictions that leads to under-provision of commons. In our design, all treatment and control villages receive the same amount of funding, equivalent to the average cost of a field channel. To our knowledge, this is the first experimental evidence that adds this existence proof to a rich theoretical and empirical literature documenting collective action using observational designs (Bardhan 2000; Montero 2022; Putterman 1981; Wade 1988). Importantly, we show that unconditional cash transfer, without facilitation, does not resolve the status quo failure of collective action in contrast to cash transfers for private consumption goods (Egger et al. 2022; Haushofer and Shapiro 2016).

Second, we contribute to the literature on managing common pool resources (Rao and Shenoy 2023; Ryan and Sudarshan 2022; Sekhri 2011). Much of the literature has focused on groundwater extraction and use empirical strategies requiring strong assumptions on causal identification. We contribute by showing that even when there are no constraints in extracting water, as in the case of surface irrigation (Rodell et al., 2009), giving agency to local community

[3]Recall that farmers in around 20% of the cost-neutral control villages got together to construct and maintain one or more channels in the study ayacut, although not necessarily the socially optimal one.

in the choice of the channel location could generate regressive distribution. Obtaining private willingness to pay to calculate the social optimal appears to be a better institutional design since it resolves the fundamental information problem. With modern technologies for high frequency monitoring (Muralidharan, 2019), including remote sensing and detailed cadastral records with state agencies, estimating the marginal value of irrigation is plausible. This paper provides a proof of concept to show that there are instances when real-life implementation of local community choice, for example through ballot voting referendum initiatives, could diverge from social optimum. In such a situation, policy makers can target policies on resolving externalities towards the social optimum.

Third, this paper sheds light on how best to design a CDD program. The typical design of an evaluation of CDD programs in the literature involves comparing a treatment group of villages that receives both facilitation and funding for an intervention to a control group that receives no intervention at all (Casey, 2018; Casey et al., 2012; Qian, 2015). Such design cannot, therefore, disentangle the impacts of the participatory approach via facilitation from the funding itself and cannot address issues that are key to answering the research questions on the optimal role of local communities in development programs. While the bottom-up approach has been tried in contexts of conflict with weak or absent government where a comparison with more standard top-down implementation was infeasible (Beath et al. 2017; Casey et al. 2012), our context allows us to compare the bottom-up implementation to one where a third party decides the location and constructs the infrastructure with limited community involvement.

Finally, because participation may be costly, particularly for the poorest individuals, we study the optimal level of community engagement by including in the design two different degrees of community participation: the location decision that involves a referendum vote at a nearby ballot location and the actual construction of the channel that may require a few days of labor or earth-moving equipment. We examine the time and money spent participating in each of these two activities as well as the (cumulative) benefits from each. Empirical evidence on the cost-effectiveness of community participation is limited, and to our knowledge, ours is the first study that tries to measure the cost of participation separately for deciding the location from the cost involved in the actual construction of the project. This comparison isolates the role of community participation in choice relative to implementation (see e.g., Dal Bó et al. 2010 for a lab approach), where we find that there are differential costs in participation in the selection process, many of which are unobserved costs such as turning out to vote.

The rest of the paper is organized as follows. We describe the context of the study in greater detail in section 2 and elaborate on the research design and data sources in section 3. We document the reduced form results in section 4. We discuss the results in light of optimal institutional design and policy and conclude in section 5.

2 Context

We study surface irrigation allocation and provision of conveyance infrastructure through field irrigation channels (unlined, mud channels) connecting local village-level water reservoir (called minor irrigation tank) to downstream agricultural plots within its command area (see Figure 1 for a schematic). Tank irrigation is common in large parts of Southern and Western India, where surface run-off from rains are captured and stored in small-scale man-made reservoirs. These structures are complementary to groundwater irrigation through recharge from percolation. Thus, not only is surface irrigation cheaper socially (with lower cost of extraction compared to groundwater extraction that requires huge upfront investment and continuing electricity costs for pumping). Despite this, tanks and surface irrigation infrastructure are poorly maintained because they are a common pool resource.

Collective action problem in this context arises out of positive and negative externalities accruing to farmers based on the location of their plot within the command area and their access to alternate sources of irrigation such as groundwater. The problem is as follows: An upstream farmer (one with plot in the head-end) has a geographic advantage in accessing irrigation from the reservoir. Since paddy is tolerant to excess water but intolerant to its absence, head-end farmer ends up using more water than optimal. This reduces the amount of water available for downstream farmers, imposing a negative externality on them. Further, if a tail-end farmer invests in constructing a channel leading to his plot, he cannot exclude the head-end farmer from accessing water since the channel has to pass through head-end. This generates a positive externality on the head-end farmer whereas the cost is borne by the tail-end. This situation leads to a "race to bottom", leading to under-investment in the provision and maintenance of surface irrigation infrastructure.

Our fieldwork and qualitative surveys shed light on cooperation failures among farmers. We find that constituent farmers rarely conduct public meetings, and even in a few contexts where farmers meet, it usually depends on local characteristics and history. In most villages we visited, the last meeting took place many years ago. Any maintenance work is usually allocated by an influential farmer (asami), or someone appointed by him.[4].

In addition to concerns of maintenance, there are no specific rules that are consistently followed in allocating irrigation water among farmers. In some villages, surface irrigation is continuous -'continuous flow irrigation' (Wade, 1988). In other villages, farmers allocate water using the depth of standing water on each plot. In Telangana, the consensus is that a farmer has the right to flood his or her plot until the standing water is 6 inches deep. This is known as "depth-based allocation". Other system such as "Warabandi" or "Taiband", common in north

[4]There is no clear pattern on who allocates volunteer labor, which has been observed in some villages while absent in many others

India, Pakistan, and few parts of southern India, involves a rotation system of irrigation allocation that is based on the number of days that the outlet to a plot is open to the channel.

This collective action problem is exacerbated by the differences in the cost of access to irrigation via field channel, a function of distance downstream from the tank. All farmers in the ayacut grow paddy, and paddy farmers prefer to keep their fields flooded continuously, since paddy is intolerant to drying but highly tolerant to excess water. The uneven cost of access contributes to the unequal production outcomes as we find in a survey of about 2,000 farmers across 92 villages from a related study.

Table 1 presents the summary statistics across the study sample and by the different experimental groups. Each ayacut in a village in the study is about 100 acres of paddy cultivated areas, with 40-45 constituent farmers, each cultivating an average of 3.5 acres (mainly smallholders). There are 3 proposed location of channels within each of the ayacuts, each of which were deemed feasible to construct. The average valuation from construting these channels amounts to around 30 additional days of irrigation, as elicited during baseline, amounting to a value addition of about INR 4500 ($55).

2.1 Conceptual Framework

A solution to overcome this problem is to internalize the externalities by a centralized authority, who would incur the cost of providing the common good as a social planner. However, the central authority can also leverage the utility derived from community engagement in the selection as well as construction process to improve the aggregate welfare. This ancilliary welfare improvement arises from monitoring the quality of construction, volunteer labor contribution, and ongoing maintenance from the local community to ensure that the good lasts multiple seasons.

Two key levers to induce community participation in any development program is by either giving communities a choice over the location of the public good, or giving them agency over implementation or a combination of both, which helps overcome two important problems in centralized public good provision. First, giving community agency over choice of the good (i.e. location) resolves the problem of information asymmetry - that of eliciting local preferences, which may not be observable to a social planner. A common method of eliciting local choice is through a referendum, which however provides equal weights to the preferences of head-end and tail-end farmers.

On the other hand, the social planner could collect data on private willingness to pay to address this concern, especially due to the imperfect weighting and other strategic behavior in the referendum process.

Second, involving the community in construction of the public good accounts for the agency problem present among the agents of the central authority, i.e. the construction workers or the project manager. Community involvement ensures that the construction is of good quality (for example, uniform width and depth of the channel) and voluntary contribution of labor or other inputs that maximizes the aggregate welfare. Additionally, both these aspects could increase overall community satisfaction with the public good.

We test for these alternate theories of institutional design to resolve the collective action problem in the context of irrigation infrastructure maintenance and allocation.

3 Research Design and Data

We conduct a randomized control trial (RCT) where we vary (a) whether the location of the channel was chosen by the community through referendum via ballot voting or by a central agency and (b) whether the construction of the channel was undertaken by the community or a third party.

3.1 Description of treatments

The intervention follows a 2-factorial stratified RCT varying how the location of the channel is chosen (choice-arm), crossed with how it is constructed (implementation-arm). All treatments are randomized at the tank-ayacut level and since we only include one tank in the study per village, treatments are also randomized at the village level. We stratify the randomization by district since our sample of villages span multiple districts with different agronomic conditions. The experimental groups arising from this include:

1. T1 (Ballot Top-Down): Location chosen by local village community via a referendum (simple majority) with channel construction carried out by an external contractor identified by a central agency.

2. T2 (Ballot Bottom-Up): Location chosen by local village community via a referendum (simple majority) with channel construction also carried out by local village community.

3. T3 (No Choice Top-Down): Location chosen by a central agency with channel construction carried out by an external contractor identified by the same agency.

4. T4 (No Choice Bottom-Up): Location chosen by a central agency with channel construction carried out by local village community.

In addition to the 2x2 matrix implied by the two-part randomization, the design also includes a cost-neutral control group (C). Farmers in this control group receive the cash equivalent of the per-capita cost of the total project but the choice of location or construction are not facilitated.

In each study village, we worked with a group of key informants to identify potential locations for 2-3 channels that were feasible for construction. Subsequently during the baseline survey of the sample plots, we asked respondents (farmer cultivators of the sampled plots) to state how much they would be willing to contribute for the construction of each of these channels previously identified by the key informants. The channel chosen under "No Community Choice" is the one with highest aggregate valuation from this private elicitation exercise. In all the "Ballot" treatments, we gave each farmer cultivator a ballot card with the location of the 2-3 feasible channels identified earlier, covering all those farmers associated with the universe of plots within the ayacut. We told these farmers to select one location of their choice (one farmer-one vote) by indicating so on the card and to deposit the card in a box kept at a prominent place before the end of 3 days from the time of our communication.[5]

Ex-ante, we expected that in a majority of cases, the most preferred channel from voting should coincide with that obtained from the elicitation exercise. However, the most voted channel could differ from the most valued one, for example, if there was vote-buying, or elite pressure, or some form of coordination between farmers. We will verify the extent to which both these methods align, so that the channels thus selected will be a valid counterfactual. In cases where they differ, we plan to execute an analysis that explores the determinants of these disagreements.

3.2 Empirical Specifications

The empirical specification (long-form) is as follows:

$$Y_{ivdt} = \delta_d + \delta_t + \sum_{j=1}^{4} \beta_j T(vt)_j + \epsilon_{ivdt} \tag{1}$$

$$Y_{ivdt} = \delta_d + \delta_t + \sum_{j=1}^{4} \beta_j T(vt)_j + \mathbf{X}_{ivdt}\Gamma + \epsilon_{ivdt}$$

In this equation, d indexes the district, v indexes the ayacut (a village) in our sample, i indexes sample farmer (some specifications are at the ayacut-level itself), and t indexes data

[5] Due to COVID19 pandemic, we could not conduct a polling day in the village that would have led to queuing up of farmers to cast their votes.

collection round/agricultural season. The leave out group is the cost-neutral control group. All the treated variables switch on after the baseline round. Standard errors will be clustered at the level of treatment assignment, i.e. at the ayacut level (Abadie et al., 2022). Our base specification does not include any controls since the specification is implemented as a Differences in Difference (DiD) design. For robustness, we will include baseline variables that remain unbalanced as controls, where $\mathbf{X}_{ivdt}$ represents a vector of such baseline characteristics.

We account for multiple outcomes using two approaches: First, we generate a single summary measure (index) for each class of outcome in standardized units, either using Principal Component Analysis (Kling et al., 2007) or standardizing the variables in the index and then adding them. Second, we will test each family of measures (under different groups presented under the data section - ayacut-level measures, farmer-level measures, and plot-level measures) jointly using family-wise error rate (FWER) corrections. We plan to also address the concern for multiple hypotheses using rich theoretical framework linking our intervention design with measures of collective action and production outcomes.

Predetermined Variables as Controls We use the following variables for balance check after random assignment: tank area; tank storage capacity; ayacut area; history of past repairs; number of plots in ayacut; number of cultivating farmers in ayacut; number of feasible locations of irrigation channels within ayacut; value of highest elicited channel; farmer (cultivator)-level demographics - age, gender, jati, total landholding, total irrigated land, sample plot-area, presence of borewell on plot.

First, we account for baseline measures that remain unbalanced after the random assignment. Additionally, we control for include the following: (a) deviation between the channel selected from the ballot exercise match the highest-valued channel from the private elicitation exercise at the aggregate ayacut level, (b) demographic details of persons in-charge of channel construction under bottom-up construction, (c) a summary index for baseline measures of collective action - joint sale, joint input purchase, joint investments (e.g. transportation to markets), and baseline-level of trust between farmers.

Second, in order to discipline our selection of control variables, we will implement the post-double-selection method of (Belloni et al., 2014) to identify the subset of the control variables from above.

3.3 Data

We collected data using primary surveys administered to farmer-cultivator of the sample plots, and investigator-led random audits with our field implementation partner J-PAL South Asia at IFMR. Specifically, we collected the following self-reported (survey) data: (a) a set of feasible locations for channel construction within the ayacut from key informants, (b) a listing census of ayacut plots and its owners, (c) a baseline survey containing private elicitation of preferences over the feasible set of channel locations under (a), (d) the number of valid ballots cast for each channel in ballot villages, (e) follow-up survey data collected via phone surveys on various satisfaction and cost of participation measures during and post intervention, and (f) a comprehensive endline survey containing detailed agricultural production measures for all cultivation seasons during the year following the intervention, including wet (Kharif) as well as dry (Rabi). Finally, measured the quality of channel construction including the dimensions of constructed channel relative to the initial specification through random site visits and measurements by trained enumerators.

A key innovation of this study is the measurement of baseline preferences over a list of all proposed channels by our sample farmers that are feasible for implementation. Specifically, farmers in the ayacut were asked to provide a valuation for each channel based on the number of additional days of surface irrigation and additional revenue earned. From this, we identify the channel that maximizes aggregate welfare within an ayacut. This is unique in the literature where most studies on community participation do not document ex-ante preferences of each community member. Further, this mechanism of identifying the socially optimal public good (channel) hasn't been tested in field settings, including in agricultural systems. In the absence of such a system, selection of public goods has hitherto been determined in an ad-hoc manner by either village elites or through Gram Panchayat (elected village council), which may only cater to the preferences of select groups at the expense of collective welfare.

We collected several primary and secondary outcomes as well as intermediate outcomes related to the construction of the channels.

Intermediate Outcome: Tank-Level Community Effort These include the first-stage measures of type of the public good (channel), including: (a) whether a channel is constructed, (b) status, including deviation, of the constructed channel relative to the initial proposed design (length, width, depth, geotrace polyline) at multiple time periods post construction, (c) duration of construction, (d) local labor hours used for construction, (e) whether machinery is used to dig the channel, and (f) total realized cost of construction (including deviations from the budgeted cost). We will use a summary index measure combining all the above components of the first stage, in addition to examining these separately.

Intermediate Outcome: Farmer-Level Coordination These include: (a) complementary investments by ayacut farmers (effort cost incurred during construction and maintenance including voluntary labor contribution, monitoring costs, cash and material support) as a measure of local community effort, (b) farmer satisfaction with participating in decision-making and construction of the channel, (c) measures of trust between farmers with plots in different locations within the ayacut, (d) farmer-level voting outcomes (whether aligned with private elicitation, and whether voting influenced by others in the village), and (e) cost of participation in voting (time cost involved in voting) and implementation (hours worked beyond compensation).

Primary Outcome - Plot-Level Access to Irrigation These include: (a) surface water availability at sample plots in various locations (head, middle, tail) within the ayacut (extensive margin - whether receives, as well as intensive margin - number of days), and (b) extent of water-related conflicts (number of conflicts, number of farmers involved in the conflict).

Primary Outcome - Plot-Level Production We will examine total production (quantity produced) and total yields (qty per acre), in aggregate as well as on average across a random sample of ayacut farmers. Usually, farmers in the ayacut grow paddy since paddy requires irrigation. We will verify the crop grown so that the production outcomes are specific to crop grown.

An important outcome relating to our research design is the cost per unit increase in aggregate agricultural production output - cost per unit increase in quantity of output, cost per unit increase in yield.

Secondary Outcomes - Plot-Level Climate Change Mitigation and Adaptation Two important consequences of helping overcome coordination and collective action failures in the context of irrigation management are climate change mitigation and adaptation. First, reliance on surface water for irrigation minimizes extraction of groundwater resources, addressing climate change mitigation. We measure the extent of groundwater use at the sample plot-level, both on the extensive margin (number of plots with functioning well) as well as on the intensive margin (number of days). Second, increase in access to (whether sample plot has access to tank water through field irrigation channels) and the extent of (number of days) surface irrigation through rainwater harvested in the tanks addresses climate change adaptation to increased drought conditions (specifically, aiding cultivation during the dry season or wet seasons with low rainfall).

Secondary Outcomes - Plot-Level Production Cost and Revenue These include plot-level measures of cost and revenue from agricultural production: (a) sales revenue by crop-season, and (b) expenditure by crop-season and expense-type (i.e. labor, capital, fertilizers and input). Since we don't expect prices to change due to our treatment, these are secondary outcome measures.

Secondary Outcomes - Village-Level Agricultural Wages by Gender Since paddy is typically the main irrigated crop cultivated within the ayacut, the gender dynamics are particularly important to study given the substantial role played by female agricultural labor at various stages of paddy life-cycle. We collect detailed agriculture wage data, by gender and agricultural task.

3.4 Sample Size and Power

Based on pilot data, we found that about two hundred villages with 30 farmers/plots per (village-level) ayacut generates statistical power at 80 percent under significance level at 5 percent to observe even a modest treatment effect using access to surface irrigation as a key outcome. We simulated statistical power using the estimated empirical effect sizes from this pilot we conducted in similar villages.[6] We include more villages than the required sample size allows us to account for any compliance or take-up issues at the time of intervention. Therefore we sample 20% more villages/tanks than required, generating a study sample of 240 villages.

We draw a stratified random sample of upto 30 plots per ayacut, stratified by plot location (i.e. head, middle, and tail), from a complete census listing of all plots in the ayacut that includes the name of the cultivating farmer associated with each plot, generating $\approx$ 7200 sample plots across 240 study villages.

We use stratified sampling of plots due to the differences in outcomes and bargaining options faced by farmers based on the location of their plot. We attempt to draw equal number of plots from head, middle, and tail portions of the ayacut. In practice, however, some ayacuts have less than 30 plots and/or some location strata with less than 10 plots. In such cases, we sample the universe of plots within the ayacut/strata. Finally, a small fraction of farmers cultivate multiple plots within the ayacut whereas a majority of farmers cultivate only one plot. Since we sample at the plot-level, we interview the same farmer if more than one of their plots are sampled.

Plot-level Sample Expansion: Post-construction of the irrigation channel, we will additionally sample all plots along the irrigation channel not covered by our baseline sample of plots, including along the channel that could have been constructed (as per elicitation data) in the control group.

4 Results

We discuss the Intent-to-Treat estimates following the randomized assignment of the various institutional designs on choosing and constructing a field irrigation channel on irrigation allocation, agricultural outcomes, and the specifics of program implementation.

[6] We note that during the pilot we had 100% compliance. All treated villages constructed the channel while none of the control villages did. This also largely holds true except that 20% control villages constructed channel, which was allowed in our research design.

4.1 Channel Construction

We find that all treatment villages construct one or more channels compared to only 20% or 6 (of 48) cost-neutral control villages. The cost of construction are uniform across the treatment villages and we distributed the average cost of construction among constituent farmers in the control villages, without any conditions. At the time of informed consent, we gave a brief overview of the study details but did not insist that the farmers had to use the cash towards creation of the channel and the final use was their own individual decision in control villages. In treatment villages, we transferred the cost of the construction based on receipt of bills from local communities in the bottom-up implementation group (96 villages) and paid directly to the contractors in the top-down implementation group (remaining 96 villages).

We also collected our own administrative data on the construction process, where we recorded the number of visits, difficulty in completing the intervention, timeline delays, and points of stress between the field research team and local communities. We document the results along these governance-related outcomes in Table 2. Interestingly, we find that the construction process was easiest to implement in ballot villages, where the local communities had agency over choosing the location of the constructed channel. We faced delays in completing the construction, requiring additional visits by the field research team, and were asked to construct additional channels in bottom-up implementation villages.

4.2 Access to Irrigation

Figure 2 and Figure 3 depicts the effect of the different interventions relative to the cost-neutral control on the number of days of irrigation in total as well as dis-aggregated by source (surface vs. groundwater). Table 3 is the table equivalent of these graphs.

First, we note a substantial increase in the number of irrigation days across different sources among the treatment groups compared to the cost-neutral control group. This isn't a surprise since fewer channels were built in the control due to persist collective action and coordination failures. The increase in the total number of days of irrigation is in line with the expected increase upon channel constructed as elicited during baseline. This assures that the increase is not due to response bias.

Second, the increase in irrigation is lower in referendum villages (choice via ballot) relative to villages where socially optimal channel is built (no-choice). The magnitude of difference is around 10 days or 25% of the increase in irrigation (0.2 SD units in effect size) relative to no channel in control.

Third, we find no difference in irrigation allocation based on who constructs the channel. Recall that in one half of the treatment villages, we let the local communities construct themselves whereas in the other half, we hire third-party contractors to construct the channels. In both the implementation arms, the entire cost of the construction is provided by us but we do not prevent the local communities from tweaking the design or increasing the length of the channel on their own cost beyond the initially agreed upon design specification. We are unable to reject any differences lower than a 0.02 effect size, which is small enough to infer that there are practically no differences in the design of actual implementation process.

4.3 Agriculture Production and Its Cost

The increase in irrigation has a direct effect on the cost of agricultural production. Figure 4 shows that the distribution of labor costs shifts to the left in all treatment villages compared to the cost-neutral control. This is plausibly due to the nature of the crop under cultivation in these areas - paddy. Paddy is historically grown in irrigated areas such as river deltas or within the command areas of irrigation schemes, including within the ayacuts of this study. Local agricultural experts in our context refer to paddy as a "lazy farmers' crop" because of its high water tolerance relative to weeds. As a result, farmers prefer keeping their paddy fields flooded if they have access to irrigation to reduce the need for weeding labor. We also find suggestive evidence on lower agricultural wages to female labor who are mainly engaged in weeding labor (Table 4).

On the other hand, we find no meaningful increases in yield or crop productivity. Recall again that this is because the control group receives an average of 100 days of irrigation, which is probably why we don't see any yield response for the additional days of irrigation beyond the high base-levels.

4.4 Status of the Infrastructure at Endline

We went back to the study villages three agricultural seasons (1.5 calendar years) following the construction of the channels to examine the status and use of the constructed channels. We carried out unannounced, in person audits of the tank ayacut and constructed channels, speaking with farmers and others, whoever were present at the site.

Table 5 documents the results from this exercise. We were able to carry out our inspections in 238 of 240 study villages, with no differential challenges to complete the inspection by the experimental status. Overall, more than 60% of the constructed channels in the treated villages continue to be functional during these visits. The channels were about 300 meters long in all the treatment villages. However, it was more likely that the constructed channel could reach tail-end in villages where local communities constructed the channel (bottom-up implementation). There were no significant differences in the structure of the tank infrastructure, such as the number of days sluice gates were open in different seasons.

4.5 Cost of Community Participation

We asked questions about cost of participation, both in terms of time-use, including voluntary contribution of labor, and any additional cash matched-up by the constituent farmers. We find that the costs are much lower in all of the treatment groups relative to the cost-neutral control group, where about 20% of the villages pooled the cash given to individual farmers to construct field irrigation channels (see Figure 5). On the other hand, the additional time and match-up cash contribution was lower in intervention villages, where we, the third party facilitated channel construction. Note that it is not just the cost of the construction, since its equivalent was distributed among farmers in the control villages as well. Thus, this suggests that external facilitation reduced the coordination and communication costs required for collective action among constituent farmers of tank ayacuts.

4.6 Distributional Implications

In addition to the average effects of the interventions, we find substantial distributional implications depending on the specific design of the intervention. Coming back to irrigation allocation and the lower average number of additional days of irrigation in ballot villages relative to no choice, we find that the average effects masks substantial heterogeneity by underlying baseline characteristics of constituent farmer groups. Following our prespecified heterogeneity analysis, we find a regressive distribution of irrigation water based on baseline value of additional unit of irrigation.

We examine baseline willingness to pay for constructing a field irrigation channel based on three important characteristics of farmers with plots in the ayacut: (a) those with access to private sources of irrigation through bore-wells, (b) those with plots within the head-end region of the command area, which have natural advantage in access surface water, and (c) size of landholding, which also signifies the extent of elite power among the constituent farmers.

We find that all three groups do not anticipate any additional days of irrigation or higher expected revenue from channel construction. In fact, farmers who were not in these categories were more likely to experience higher revenue from more addition from the constructed channels. However, large landholders elicited a large willingness to pay for field channels in private, suggesting other unobserved costs that could be driving their baseline willingness to pay beyond anticipated additional revenue (see Figure 6).

Surprisingly, all these three groups report higher number of additional days of irrigation in ballot villages relative to their counterparts in no choice villages. Specifically, these groups receive 10-40 days of additional irrigation compared to constituent farmers not in these groups only in ballot villages. In contrast, there is no substantial difference by such group heterogeneity in no-choice villages, and if anything farmers with wells get fewer days of additional irrigation. The group-based heterogeneity within no-choice villages is in-line with the baseline valuation, suggesting that selecting the location of the channel based on maximizing the ayacut-level private willingness to pay represents a socially optimum outcome without concerns about equity (see Figure 7).

What could cause this divergence between ballot and no-choice interventions? The average turn-out of constituent farmers in dropping off their votes in the ballot was low at 43% but not dissimilar from turnout at general elections. Figure 8 (left figure) shows turn-out by the above-mentioned farmer groups. Despite a lower willingness to pay at baseline, farmers with head-end plots and large landholders are more like to turn out to vote. Further, we found that many of those that voted, did not vote for the channel that maximized their private value. Specifically, those with borewells that voted are less likely to vote for their privately optimal channel. Finally, we find that the channel constructed closely aligns with large landholders in ballot villages (right figure). These suggest that the referendum initiative may not have been the perfect mechanism to capture social choice and that there may have been strategic behavior on part of the voters to enable elites get their choice of the location.

5 Discussion and Conclusion

In this paper, we show that there are advantages in learning about each community member's private preferences before the start of any development project. The standard approach has been that of centralized intervention, particularly when there are substantial externalities, with the assumption that the private agents find it not optimal to come together to successfully internalize the externality. On the other hand, there are examples of many local institutions that exist to resolve this problem without centralized interventions. Many scholars and practitioners champion these latter approaches given the advantages of local communities in having information about their own preferences and being better in monitoring and enforcing contracts in principal-agent problems. However, such institutions are not common and we know very little about when and why successful cooperation arise.

We design an experiment where we vary different aspects of an institutional design to construct field irrigation channels, where the status quo indicated Pareto inferior equilibrium of few functioning channels even when community members (farmers) desired more. We vary whether local communities are involved in choosing the location of an irrigation channel through referendum voting and also whether these communities have agency in constructing the channel themselves. Importantly, we collected detailed production and private willingness to pay for each possible channel location at baseline. With this information, we were able to identify a social planner benchmark that identified a location that maximized the aggregate welfare across constituent farmers to compare against the outcome of referendum. Additionally, we also had a cost-neutral control group, where no field channel construction was facilitated to identify the existence of collective action problem.

The key implications of our study are the following: First, collective action and coordination problems lead to under-provision of commons such as irrigation infrastructure provision and maintenance. External facilitation of different forms can enable communities move out of this trap to a better equilibrium at a much lower cost to them. Second, referendum is not an ideal approach to identify social choice - the channel selected via voting diverges from the social optimum is close to half of the referendum villages. This could be because of poor turnout and plausible strategic behavior among voters. Further, subsequent allocation of irrigation water within referendum villages are regressive - farmers with lower marginal value get more irrigation than those with higher marginal value. In contrast, the social planner benchmark of selecting aggregate welfare maximizing channel outperforms. Third, involving local communities in the construction has no substantial effect on either water allocation or other welfare outcomes. To the contrary, this may delay the project timeline and increase visits by external facilitators to ensure timely completion.

Thus, for a policy-maker, it is important to learn about individual-level preferences since eliciting social choice is hard. The next step in this research agenda would be to collect data on private willingness to pay at scale. With modern technology and individual-level administrative data, this should be plausible. On the other hand, the actual implementation of development projects could be centralized as there are no immediate advantages that we could detect at our timescale. It is plausible that giving agency to local communities could strengthen their capacity in the long run, which remains an open question for future research.

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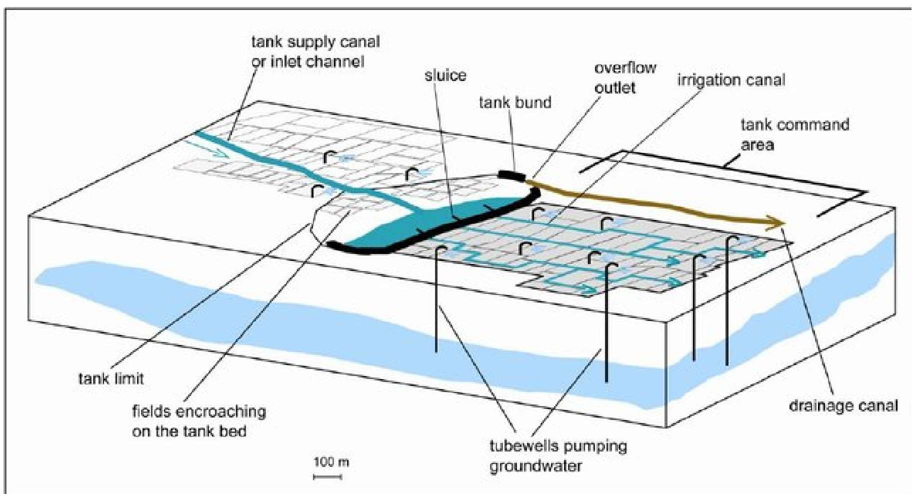
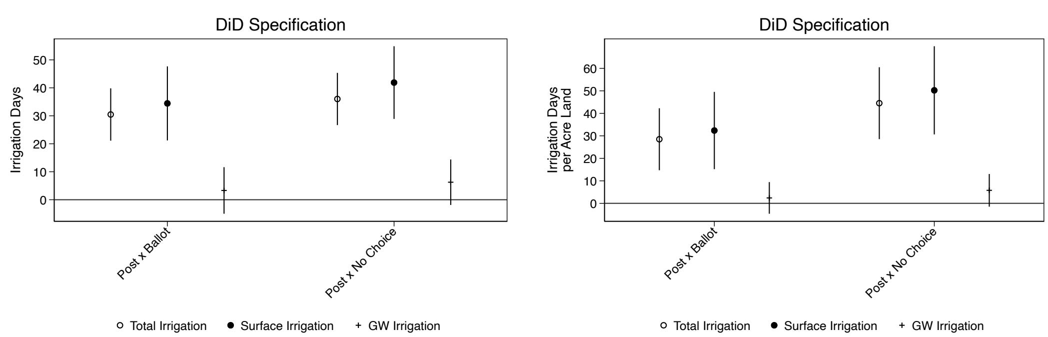
6 Figures

Figure 1: Structure of Minor Irrigation Tank



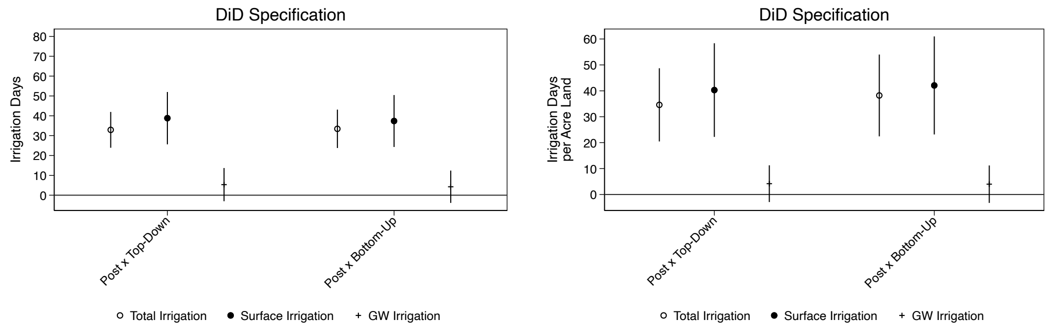
Notes: Image source from Mathevet, et al, 2020.The figure above provides a schematic of a typical tank irrigation system with downstream plots, some of which also have access to groundwater sources of irrigation.

Figure 2: Irrigation Allocation: Choice vs. No Choice



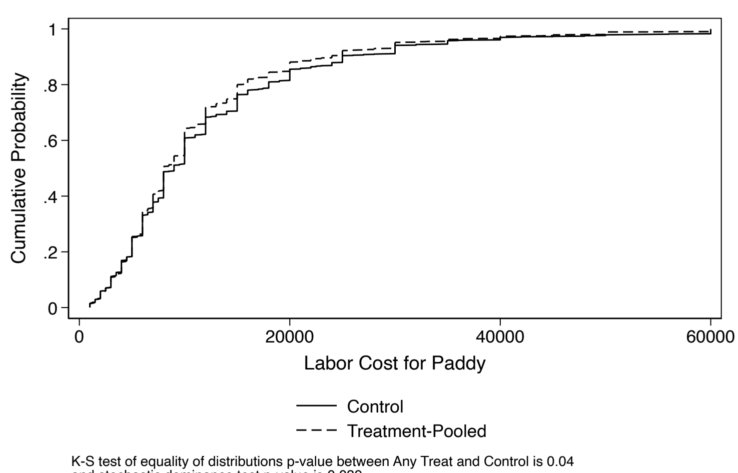
Notes: The figures above present the ITT estimates on number of days of irrigation unadjusted for land area (left) and adjusted for land area (right). The effects are substantial when compared to the budget-neutral arm where no channel is constructed in 80% of the control group. The increase in the average number of days of irrigation is consistent with the expected increase in about 30 additional days of irrigation anticipated at baseline. The differences in the estimates between ballot and no-choice are also statistically significant at 10% and 5%, respectively (unadjusted vs adjusted). This difference represents a 15 day increase in irrigation per unit land under social optimum representing an effect size of 0.2 standard deviation units. Standard errors are clustered by village/ayacut and the specifications include randomization strata fixed effects.

Figure 3: Irrigation Allocation: Top-Down vs. Bottom-Up Implementation



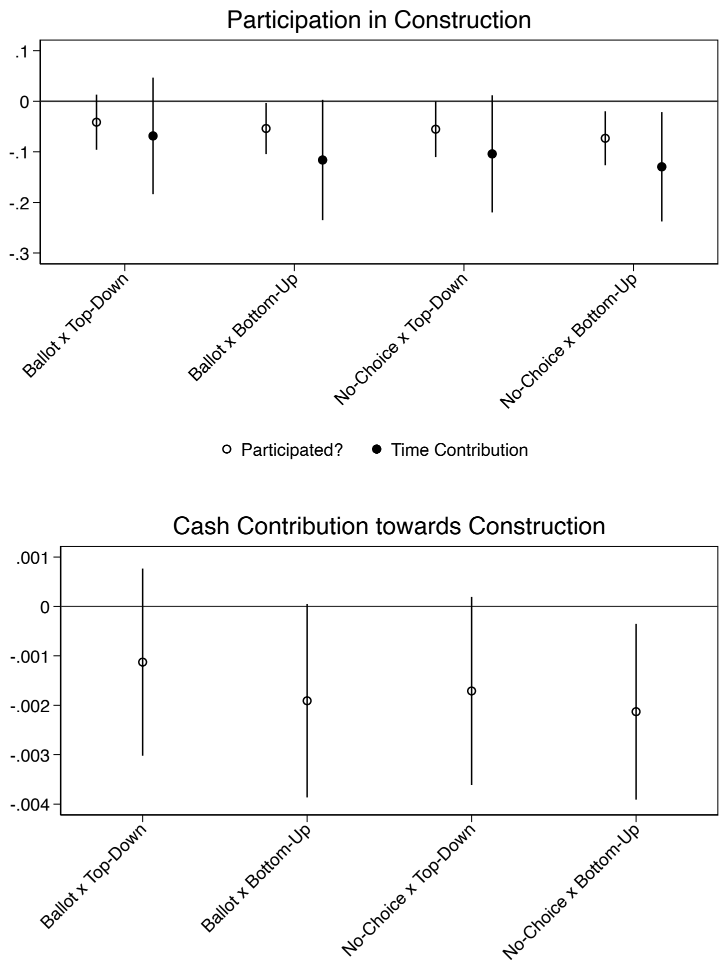
Notes: The figures above present the ITT estimates on number of days of irrigation un-adjusted for land area (left) and adjusted for land area (right). As seen before for the choice intervention, the effects of any implementation intervention are substantial compared to the budget-neutral control group. However, the differences between the specific type of implementation - top-down and bottom-up implementation - are neither statistically significant nor meaningful in effect size. We are unable to reject any effect sizes lower than 0.02 standard deviation units (p-values>0.5). Standard errors are clustered by village/ayacut and the specifications include randomization strata fixed effects.

Figure 4: Labor Costs of Production



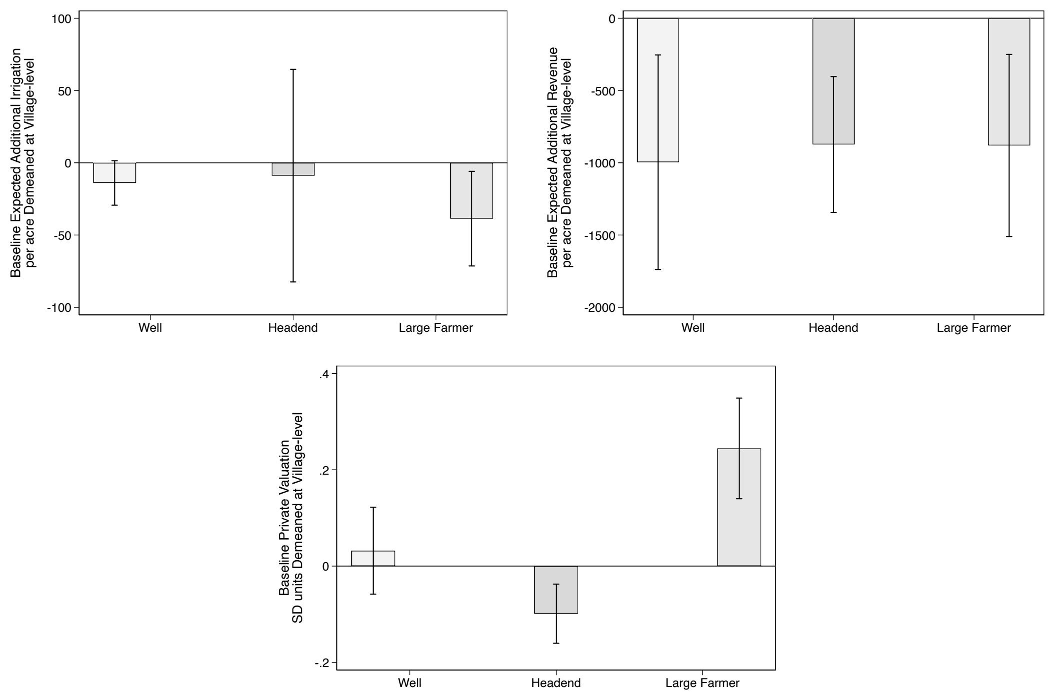
Notes: The figures above present the CDF of labor costs across all the channel intervention groups (Treatment-Pooled, depicted by dashed line) and the budget-neutral control (Control shown by solid line). We carry out two specific tests: Kolmogorov-Smirnoff test of equality of distribution, which we reject at 5% and stochastic dominance test, which is also significant at 5%. These suggest that the labor costs of paddy production is lower across all scale of production in villages that received an irrigation channel compared to the budget-neutral control where only 20% of the villages constructed a channel by their own.

Figure 5: Costs of Participation



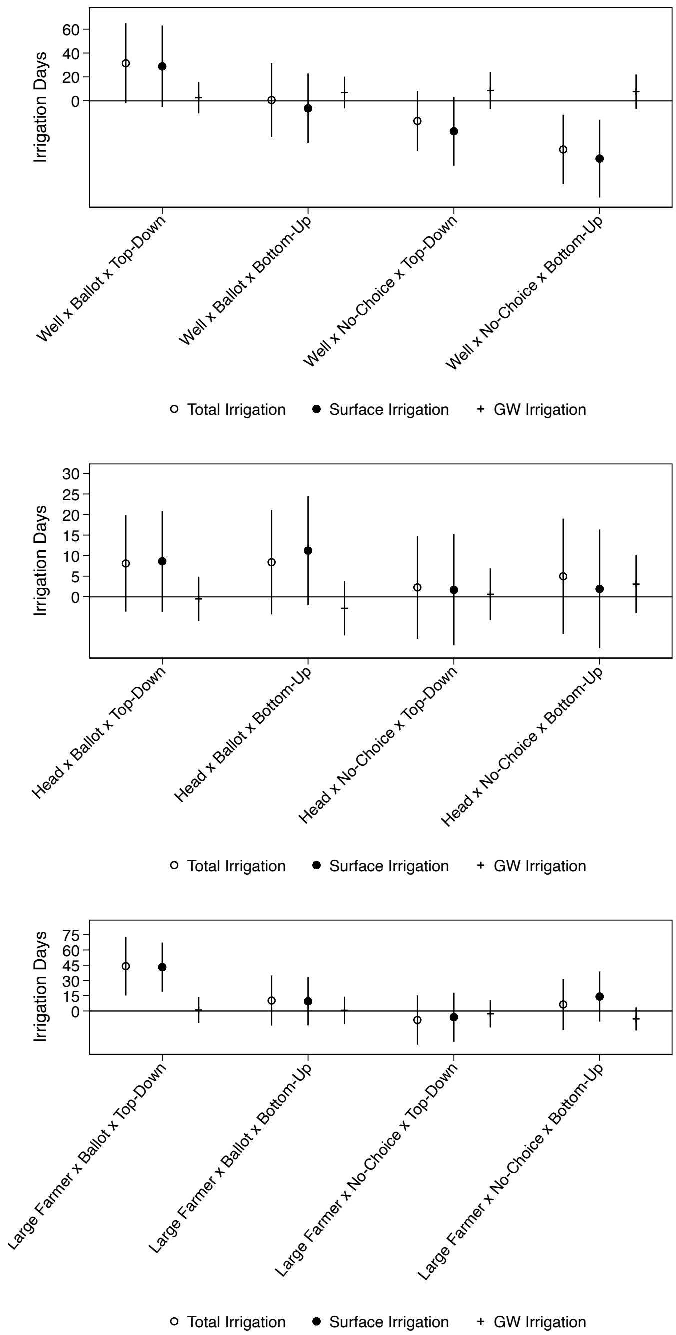
Notes: The figures above present the cost of participation in the construction and upkeep of any field irrigation channel in the study village/ayacut based on two survey questions - whether or not the respondent farmer participated in the construction (top) and how much cash they contributed towards the construction (bottom). The comparison/leave-out group is the budget-neutral control where some of the villages overcame the coordination frictions in construction some channel on their own, without our facilitation. Standard errors are clustered by village/ayacut and the specifications include randomization strata fixed effects.

Figure 6: Baseline Private Willingness to Pay by Farm Characteristics



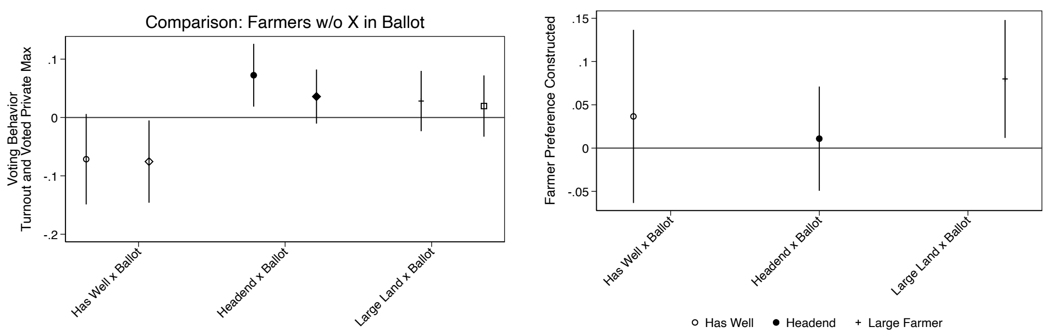
Notes: The figures above present the baseline willingness to pay elicited during private, in-person surveys across all study villages before the random assignment of the various interventions. In the elicitation, we collected additional days of irrigation anticipated from each feasible channel (that was later put on the ballot), additional revenue earned from increased irrigation, and the final stated willingness to pay (private valuation). We present the deviation from average values at the village-level by specific, pre-specified characteristics of farmers - whether they have a functioning well on their plot, whether their plot is in the head-end location, and whether they are large landholder. Standard errors are clustered by village/ayacut and the specifications include randomization strata fixed effects.

Figure 7: Irrigation Allocation Heterogeneity



Notes: The figures above present the heterogeneous treatment effect estimates on number of days of irrigation by three different, pre-specified, baseline characteristics. Each coefficient is the coefficient on the triple interacted term, interacting the baseline characteristics by the experimental status. The comparison group includes those without the specific characteristics in the respective experimental groups. Standard errors are clustered by village/ayacut and the specifications include randomization strata fixed effects.

Figure 8: Outcomes of Community Choice (Referendum)



Notes: The figures above present the heterogeneous treatment effect estimates on the voting turn-out behavior in the ballot initiative villages. The key outcomes include whether the respondent farmer voted, whether their vote differed from their private optimum, and whether their private preference coincides with the final channel that gets constructed in such villages. Standard errors are clustered by village/ayacut and the specifications include randomization strata fixed effects.

7 Tables

Table 1: Summary Statistics and Balance Table

	(1) Ballot Top Down	(2) Ballot Bottom Up	(3) No Choice Top Down	(4) No Choice Bottom Up	(5) Control
Area of ayacut in acres	156	90	77	125	113
	(79)	(53)	(62)	(77)	(51)
Number of farmers in ayacut	40**	45	45	44	46
	(10)	(13)	(21)	(13)	(15)
Number of proposed channels	3	3	3	3	3
	(1)	(1)	(1)	(1)	(1)
Area (Acres) Cultivated Farmer	3.5*	3.7	3.6	3.5*	4
	(3.8)	(4.3)	(4.4)	(3.6)	(5)
Additional Days of Irrigation	27	29	31	35*	27
	(40)	(56)	(71)	(180)	(42)
Highest valuation for a farmer	4923	4029	4587	4809	4615
	(11889)	(5147)	(8534)	(8089)	(8356)
No. Villages	48	48	48	48	48
No. Sample Farmers	1250	1244	1257	1278	1262
p-value (Joint Test)	0.35	0.2	0.01	0.17	0.31

Notes: The above table presents the average and standard deviation (in parenthesis) of each of the characteristics mentioned in the rows by the experimental groups in columns. Stars indicate whether specific values are significantly different from the value in budget-neutral control group. The last row indicates the p-value of joint test of equality of all the baseline characteristics determining specific assignment to an experimental group. The Difference-in-difference (DiD) implementation of our estimation strategy accounts for any significant baseline differences in the random assignment that may occur by chance.

Table 2: Administrative Data on Implementing the Intervention

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	No Data	Overall Difficulty Implementation	No. Visits Team	Delay Payment Acknowledgement	Delay Appointment	Delay Construction	Demand Additional Construction
Ballot x Top-Down	-0.0432	-0.852**	-0.797	-0.0714	-0.0771	-0.0144	0.0423
	(0.0421)	(0.411)	(0.599)	(0.0778)	(0.0848)	(0.0842)	(0.0555)
Ballot x Bottom-up	-0.0344	0.0684	0.120	-0.0325	0.118	0.0312	0.0461
	(0.0418)	(0.499)	(0.631)	(0.0816)	(0.0900)	(0.0836)	(0.0530)
No Choice x Top-Down	-0.0365	0.245					
	(0.0395)	(0.454)					
No Choice x Bottom-up	-0.0343	-0.0211	0.666	0.0829	0.0128	0.143*	0.106*
	(0.0414)	(0.453)	(0.704)	(0.0860)	(0.0924)	(0.0858)	(0.0570)
Obs	240	225	186	186	186	186	186
FE	District	District	District	District	District	District	District
Control Mean	.09	3.85	5.42	.33	.56	.51	.16
Control SD	.29	2.8	3.57	.48	.5	.51	.37
Ballot=No Ballot	.9	.18	.14	.1	.8248	.3094	.8356
Top Down=Bottom Up	.84	.38	.08	.28	.107	.1297	.1898

Standard errors in parentheses

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Notes: The above table presents the results on governance outcomes in the process of providing the intervention (channel construction) itself. Column 1 records any differential attrition in the administrative data, which we find none. Column 2 is a self-reported measure of difficulty in completing the intervention (channel construction in all treatment and cash disbursal in control) as reported by the field research team coordinating the interventions. Column 3 records the number of visits by the field research teams to enable completion of the construction. Columns 4-6 record time delays in acknowledgement/response from the communities in confirming receipt of payment, appointment for our visit, and the final completion of the construction. Column 7 records whether the community asked for additional channels to be constructed from the research team. Columns 3-7 do not include the budget-neutral control since the administrative data was about channel construction facilitation provided as part of our research design. Therefore, for these columns, the leave-out group is the No-Choice Top-Down group. Standard errors are clustered by village and the specifications include randomization strata fixed effect. Disclaimer: We could not comply with any of the study village community request to build additional channels due to maintaining sanctity to research design and to comply with our project budget. We politely convinced the communities of our study objectives during post-intervention debrief.

Table 3: Irrigation Allocation by Treatment

	(1) Total Irri Days	(2) Total Irri Days per-acre
Post x Ballot x Top-Down	33.40***	29.65***
	(7.917)	(9.259)
Post x Ballot x Bottom-Up	35.44***	35.05***
	(7.903)	(11.19)
Post x No-Choice x Top-Down	44.59***	51.42***
	(7.737)	(12.55)
Post x No-Choice x Bottom-Up	39.33***	48.97***
	(7.695)	(12.16)
Obs	24606	23271
Control Mean	91.77	93.01
Control SD	54.62	109.73
Ballot+TD=No Ballot + TD	.1756	.0801
Ballot+BU=No Ballot + TD	.2658	.2391
Ballot+TD=No Ballot + BU	.4712	.1068
Ballot+BU=No Ballot + BU	.6357	.3031

Standard errors in parentheses

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Notes: The above is a tabular version of Figure 2 and Figure 3 where we present the effects on irrigation in each of the experimental groups relative to the budget-neutral control group. Column 1 is unadjusted number of irrigation days reported by each sample plot cultivator whereas Column 2 is the per-acre irrigation days. The bottom rows record pair-wise Wald tests of equality of coefficients between each of the experimental variation in choice and implementation. Standard errors are clustered by village and the specifications include randomization strata fixed effect.

Table 4: Village-level Wage Effects

	(1) IHS(Wages) Agri Men	(2) IHS(Wages) Agri Women	(3) IHS(Wages) Non-Agri Men	(4) IHS(Wages) Non-Agri Women	(5) Wages Agri Men	(6) Wages Agri Women	(7) Wages Non-Agri Men	(8) Wages Non-Agri Women
Ballot x Top-Down	-0.00136	-0.0489	-0.0105	0.00268	4.688	-27.54	-7.128	-4.443
	(0.0390)	(0.0444)	(0.0520)	(0.0598)	(30.34)	(23.27)	(40.96)	(29.02)
Ballot x Bottom-up	-0.0168	-0.0975**	0.0487	0.0256	-15.62	-43.75*	43.75	3.125
	(0.0389)	(0.0474)	(0.0546)	(0.0584)	(29.39)	(24.90)	(43.75)	(28.22)
No Choice x Top-Down	-0.0549	-0.0529	-0.0179	-0.00625	-43.85	-14.47	-19.62	-11.44
	(0.0371)	(0.0482)	(0.0489)	(0.0572)	(28.14)	(26.39)	(38.24)	(27.11)
No Choice x Bottom-up	-0.0251	-0.0830*	-0.0172	-0.0129	-17.71	-37.08	-15.63	-12.08
	(0.0363)	(0.0428)	(0.0503)	(0.0591)	(26.83)	(23.90)	(39.66)	(28.42)
Obs	238	238	238	238	238	238	238	238
FE	District	District	District	District	District	District	District	District
Control Mean	717.71	448.96	779.17	477.08	717.71	448.96	779.17	477.08
Control SD	226.32	191.16	214.58	164.37	226.32	191.16	214.58	164.37
Ballot=No Ballot	.2835	.8883	.2878	.5318	.2117	.6147	.1874	.5304
Top Down=Bottom Up	.8015	.2905	.3848	.8306	.8851	.323	.3131	.8443

Standard errors in parentheses

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Notes: The table presents village-level agricultural wage regressions, where wage data was collected during the endline. Agricultural labor markets are segmented by gender. Male wage laborers are paid INR 700 per day in our context whereas female wage laborers are paid around INR 450 per day. The key distinction in the labor markets are that female labor is mainly used for weeding and harvesting whereas male labor is used during land preparation and fertilizer application. Standard errors are clustered by village and the specifications include randomization strata fixed effect.

Table 5: Status of Channel Constructed at Endline

	(1) No Audit Endline	(2) Channel Status Endline	(3) Construced Length	(4) Reach Tailend	(5) Days Sluice Open Rabi 2022	(6) Days Sluice Open Kharif 2022	(7) Days Sluice Open Rabi 2023
Ballot x Top-Down	-0.000165	0.601***	294.2***	0.642***	6.540	0.908	9.653
	(0.00532)	(0.0801)	(28.23)	(0.0809)	(6.171)	(4.619)	(5.962)
Ballot x Bottom-up	0.0187	0.646***	292.3***	0.646***	1.750	-2.562	3.937
	(0.0192)	(0.0743)	(29.62)	(0.0721)	(6.003)	(4.891)	(5.916)
No Choice x Top-Down	0.0190	0.517***	300.5***	0.441***	1.582	0.0205	2.331
	(0.0195)	(0.0837)	(31.45)	(0.0838)	(6.238)	(4.815)	(6.468)
No Choice x Bottom-up	-1.63e-18	0.625***	299.5***	0.667***	7.937	3.062	10.62*
	(0.00526)	(0.0779)	(30.99)	(0.0710)	(6.079)	(4.471)	(6.002)
Obs	240	238	238	238	238	238	238
FE	District	District	District	District	District	District	District
Control Mean	0	.19	60.42	.15	47.6	79.38	45.63
Control SD	0	.39	132.07	.36	41.32	29.9	40.77
Ballot=No Ballot	.99	.3	.7607	.1	.891	.4778	.9435
Top Down=Bottom Up	1	.13	.9488	.0369	.8609	.9488	.7722

Standard errors in parentheses

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Notes: The table presents village-level data on random audits by the research team. Column 1 shows any differential attrition in the site visits, which we find none. Columns 2-4 record specifics of the constructed channel, including whether they are functional (Col 2), length (Col 3), and whether they reach the tail-end within the ayacut (Col 4). Columns 5-7 are about connections to the main village reservoir/tank. We incorporate heterogeneity robust standard errors and include randomization strata fixed effect.

Online Appendix

A Experiment Protocol and Scripts

A.1 Pre-baseline Activities

Village Sampling Frame: We used the government tank census data to identify villages with tanks above 100 acres ayacut. We called the respective Sarpanch/VRO to check whether there is tank based surface irrigation in any of the seasons (Kharif or Rabi). We recorded all this information in an excel file (data to be entered in exactly in the format provided). Details to select a village into the sampling frame will be based on the presence of surface irrigation after on-site verification by research team members.

Preparation of Command Area Maps A team of 2 research assistants sought appointment from the village sarpanch and VRA for the mapping exercise. The team conducted a focus group in the village with sarpanch, VRA, and a group of farmers representing head, middle, and tail regions, to draw a schematic map of the tank, existing irrigation channels, and identified potential locations for constructing field channels. Using the map of tank ayacut, they marked the proposed locations of the potential new channels (for example, if it is a sub-channel, they marked it so on the map) to be constructed. For reference, they also included landmarks on the maps for easy identification of the location. Next, they estimated the cost of constructing each of the potential channel. For example, if one channel would need 4 male and 4 female laborers for 2 days of work, then the cost of the construction would be the total labor cost as per the local prevailing wage rate.

Script: *We are interested in improving farmer welfare and particularly interested in understanding agricultural practices in this village. We want to understand how ayacut farmer community decide on using water from the tank (mention tank name) for surface irrigation. We will ask you and this group a few questions about tank use and make a schematic map of the tank and its ayacut.* **Draw a schematic map.**

Now, looking at this map, can you identify 3-4 locations where a new channel or sub-channel can be constructed to improve surface irrigation from the tank. Mark the location on the map. We will also be approaching the farmers to understand their cultivation practices and identify their preference for the location of the potential channel to be constructed. **Collect farmer listing data.**

Once we have completed data collection, we will either identify which channel to construct ourselves or we will hold a secret ballot so that the community can choose which channel should be constructed. Next, we will either construct the channel ourselves or provide funds to your community or farmers directly to construct yourselves. We will collect data on irrigation use and agriculture production once every growing season for the next 1-2 years. We thank you for your cooperation and we will continue to be in touch through this study.

Farmer Sampling Frame: We enumerated of all farmers within the tank ayacut, by section, i.e. Head, Middle, and Tail. For each farmer, we recorded their location (head/middle/tail) and whether they have a functioning bore-well on their plot currently. We also recorded their phone numbers for contacting for the baseline survey.

A.2 Baseline Private WTP elicitation

Greetings! We are from J-PAL South Asia organization, representing researchers who are interested in understanding and addressing the problems concerning effective usage of tank water for irrigation to increase agricultural production, yield, and ultimately farmer welfare. Towards this goal, we have come to you with X number of proposals to build channels/mud trenches (but not permanent concrete ones) in this tank's (mention name) ayacut. The locations of these channels were proposed by sarpanch, VRA, neeretigar, and asamis from this ayacut during a village meeting we organized in your village Y days ago. [ENUMERATOR Instruction: Show the map with the location and the extent of the channels.]

We want to first understand whether or not any of these channels are valued by the farmers more than the current status quo and if so, which among these have the highest value. Specifically, we want to identify one channel that generates the highest value across all farmers in the ayacut and whether this total value is more than the cost of constructing or repairing the particular channel. Please note that by valuation, we don't mean that you have to pay this amount. The valuation is how much would you gain (in money terms) from cultivating your plot in the ayacut if the channel was constructed or repaired.

Consider the following example. Under status quo of channels in disrepair, you face uncertain access to surface irrigation. Because paddy requires a lot of water, this can affect the yield. Let's assume that the revenue you earn from selling paddy under status quo is INR 30,000. Now suppose that the channel is built or repaired such that you now have more reliable access to surface irrigation. This increases the paddy yield and the associated revenue to INR 35,000. This means that the channel's value is upto INR 5000 (35000 – 30000). [ENUMERATOR Instruction: Check if this process of valuation is clear to the farmer].

If the total value of the highest-valued channel across all farmers is less than the cost of building or repairing that channel, then we may not construct or repair any channel in your village at all. [ENUMERATOR Instruction: Mention the approximate cost for each of the channel, mentioning the length and showing it on the map.]

Remember, you will not be required to pay this amount, but you need to truthfully mention your honest and independent valuation. We will add your valuation to the valuation provided by other farmers to identify which channel generates the highest value across all farmers in the ayacut. If you are not being truthful and quote a very low value much less than your true valuation, others may also do so and in such a situation no channel will be constructed or repaired.

Our organization will be facilitating the construction or repair of one of these channels through a cash subsidy of up to INR 10,000. We will either provide this money to this village (someone recommended by the initial group we met including sarpanch) to construct yourselves or we may construct ourselves.

Regarding which channel will be selected, we will either hold a secret ballot voting in the village later or we will decide the channel ourselves. If we decide ourselves, there will be no voting.

Channel construction or repair is going to cost money and/or labor. Therefore, you will only be asked to contribute the difference between how important the channel is for you relative to other farmers. Similarly, other farmers will also be asked to contribute the difference between how important the channel is for them compared to all other farmers in the ayacut. What this means is that you will only be asked to contribute if the highest-valued channel will change if your valuation for the channel is dropped when calculating the total. It may be the case that dropping your valuation will not change which channel generates the highest value across all other farmers. In such a situation, you pay nothing. However, if dropping your valuation changes which channel generates highest value across all other farmers, then, you will be asked to pay the difference between the value of the new highest-valued channel and the total valuation from all other farmers for the current highest-valued channel. We will further net out the subsidy we provide (INR 10000) from the total cost of construction and you will only need to contribute towards the additional cost of construction. You may contribute this share either in cash or volunteer to manage the construction/repair, as you deem fit. What this means is that under such a situation where the channel is more important to you relative to other farmers, you will need to take additional responsibility towards channel construction, either in terms of paying part of the cost or in kind through voluntary labor.

Note that if you artificially inflate your valuation higher than your true valuation, you may actually be required to pay some contribution which you need not if you state your valuation truthfully.

To understand this exercise better, consider the following example. Suppose there are three farmers in the ayacut – Ramu, Shamu, Bheemu. The village has proposed two channels that need to be constructed or repaired. Channel G1 costs INR 10500 and G2 costs INR 3000. Ramu, Shamu, Bheemu provide their valuations as shown in the table below:

Farmer	Channel: G1	Channel: G2	Payment (without subsidy)	Payment (with subsidy)
Ramu	5000	6000	0	0
Shamu	8000	0	1000	500
Bheemu	3000	3000	0	0

Clearly channel G1 has the highest valuation (16000 relative to 9000 for G2). Suppose this channel is selected for construction/repairs. If we remove Ramu's valuation, G1 is still the highest valued channel (valued at 11000 compared to G2 valued at 3000), so he pays nothing. If we remove Bheemu's valuation also, G1 continues to be the highest channel (valued at 13000 compared to G2 valued at 6000), so he also pays nothing. However, if we remove Shamu's valuation, then the highest value channel is G2 (valued at 9000 compared to G1 without Shamu, which is now valued at 8000). So, the difference is 9000-8000 = 1000 and this is how much Shamu will have to pay if there is no subsidy. But, remember that we provide INR 10,000 whereas the cost of constructing G1 is INR 10,500. In this case, Shamu only has to pay 500 (1000 – 500). Now, Shamu may pay this in cash or may volunteer to monitor the construction process, based on what he is comfortable with.

[ENUMERATOR Instruction: Check if it is clear to the respondent that not all have to pay some cost for channel and those that may have to pay some cost do not pay anything close to their actual valuation of the channel.]

Instruction: Once the enumerator has ascertained the understanding of the respondent, record their valuations for the different proposed channels.

A.3 Cost-Neutral Control Protocol

Field managers distribute per-farmer average cost of channel construction in the intervention villages. They used the following script at the time of cash disbursal. *Greetings! We are from J-PAL South Asia at IFMR, representing researchers who are interested in understanding and addressing the problems concerning effective usage of tank water for irrigation to increase agricultural production, yield, and ultimately farmer welfare. We collected some data from you a few weeks ago.*

We are now providing you with $\approx$ INR 300 (we gave the computed value, which is approximated 300 per farmer) as well as to other study farmers in this ayacut. You may decide to use this money together with other farmers to build an irrigation channel or decide to use this for any other personal use. There are no conditions attached to this cash.

A.4 Ballot Voting Protocol

Team size in each district: 2 surveyors + 1 supervisor No. of voting days per village: 4 days Items needed: Ballot box, ballot cards, maps, farmer list to guide and track distribution Targeted group: Universe of all ayacut farmers as per our initial listing data (in villages with bottom-up choice)

1. Day 0

   (a) Supervisor to call the Sarpanch to inform that we would start a ballot voting exercise in the village the next day for the choice of channel to be constructed.

   (b) Before starting the discussion about voting exercise, enquire about the covid situation in the village to ensure that it doesn't breach the protocol of <2% active cases in the village (this protocol will be updated in line with learnings from the early experience and how the covid situation in the state progresses).

   (c) Ask for permission to place the ballot box within the premises of the village's panchayat office for the next 4 days. If the gram panchayat office is located in another village or at a location that is not easily accessible, ask the Sarpanch to suggest a public property within whose premises the ballot box can be placed safely (for instance, any local govt office/school/ ration shop). Also ask the sarpanch to suggest a person for the box's safety who could take it in at 7 pm and place it out at 8 am for the next 4 days and ensure that the box is not tampered with.

   (d) Make sure that the ballot cards, farmer list and maps are ready.

2. Day 1

(a) Reach the village by 9 am and place the ballot box at the decided location. Talk to the person suggested by the Sarpanch and convey the purpose and details of the project in a way that they understand the vitality of the voting exercise.

(b) Place an A3 copy of the ayacut's map on the wall right next to where the ballot box is placed. Make sure that both ballot box and map are placed at a location where they are unaffected by rain/harsh weather. Post a photo of the ballot box and map taken using the timestamp app on the whatsapp group.

(c) After the ballot box is placed, go door-to-door to visit all the farmers on the list to invite them to vote. (This list includes all the farmers in the ayacut as per the initial listing exercise and not just the baseline sample). In SCTO, select all UIDs to whom the card was distributed.

(d) Convey all the necessary information as per the script below and hand over the ballot card and a map to all the farmers:

Greetings! We are from J-PAL South Asia at IFMR, representing researchers who are interested in understanding and addressing the problems concerning effective usage of tank water for irrigation to increase agricultural production, yield, and ultimately farmer welfare. We collected some data from you a few weeks ago. We now want to identify the location of the channel to be constructed through secret ballot – one farmer, one vote. I will now explain the different location choices of the channels and hand you a copy of the map. Please tick the channel that you prefer the most and drop the ballot card in the ballot box placed at location (mention the details) on or before the last date. Your vote will be anonymous. You may ask for assistance from us at the project contact number. After the vote, we will select the channel for construction as the one that receives highest votes. We will then proceed with the construction shortly thereafter.

3. Day 2: Open for voting between 8 am and 7 pm.

4. Day 3: Open for voting between 8 am and 7 pm. On this day, we would send the following reminder SMS to all farmers. *Greetings. Our team visited you last week and gave you a ballot card and a map. Your vote will help us decide which channel gets selected for construction/repair. Please make sure to drop your ballot card in the box by tomorrow. J-PAL South Asia*

5. Day 4: Visit the village and collect all the ballot cards from the box at 5:30 pm. After the cards are collected, leave the village immediately and count and upload the voting data on SurveyCTO (For each village, mark the chosen channel for each UID - NA if card is missing) after reaching home on the same day. Any discussion with the Sarpanch/the person assisting with overlooking the ballot box/anyone else in the village should only take place before the ballot cards are collected. Do not show the ballot cards to anybody. Let the Sarpanch know that the ballot box is being left behind in the village and can be used by them

A.5 Bottom-up Implementation Protocol

In addition to following the above-mentioned protocol following the choice intervention, we provide the following information in villages that were assigned to bottom-up implementation arm:

We will be providing the collected funds along with our contribution to Mr. Z from your village (mention the name), who a majority of you have unanimously appointed as the "Project Director". We will be providing 50% of the cost now to start the project by this date (mention the starting date), or when the works have started and the remaining 50% upon satisfactory completion of the sub-channel construction. We expect the sub-channel to be ready by this date (mention the end date).