The Effects of Governance on Relational and Formal Contracts: Theory and Evidence from Groundwater Irrigation Markets*

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Abstract

This paper theoretically and empirically examines the role governance institutions play in the adoption of contracts. We develop a simple model of the contracting relationship in a setting where unverifiable outcomes exist and use it to interpret data on groundwater irrigation contracts in Bangladesh. A distinguishing feature of this market is the variety of village-level institutions which impose different degrees of punishment for contract violation. We find that households adopt formal contracts when punishment for violation is severe and adopt relational contracts when punishment is weak. Furthermore, contractual form is affected by factors that affect the distribution of surplus, such as the agents' degree of bargaining power and/or availability of outside options.

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1 Introduction

When governance institutions exist to observe, verify, and enforce contracts, individuals can rely on formal agreements to manage economic conduct. However, when governance institutions are absent (Dixit, 2004) or when third-party verifiable performance measures are of low-quality (Baker et al., 1994), relational contracts may generate larger surplus than the best available formal contracts. In these cases, contracting parties can choose to exploit observable but unverifiable outcomes to engage in relational contracting. Even in situations where formal contracting is possible, parties may still prefer to use relational contracts if third-party verifiable outcomes are weak signals of agent action. How, though, do differences in the effectiveness of governance institutions change the private ordering of relational and formal contracts?

This paper focuses on the role of relational and formal contracts in resolving verifiability problems in environments where the extent of enforcement of formal contracts varies. A limiting factor in the study of the private ordering of relational and formal contracts has been a lack of data on relational contracts (Gil and Zanarone, 2017). Almost by definition, relational contracts are difficult to measure since there is no need to formalize the terms of trade. We use a novel data set from Bangladesh that records detailed information on both relational and formal agreements for the purchase of groundwater for irrigation. A distinguishing feature of this market is the existence of a variety of village-level governance institutions that differ in the severity with which they punish contract violation.

The data consist of farm production and contract information for 960 households randomly selected from 96 villages that provide representative coverage of irrigated rice cultivation in Bangladesh. Supplementing the household survey is a village-level survey designed to gather information on village governance institutions and their mechanisms for enforcing contracts. Contracts in this setting take one of three forms. A fixed price contract in which water buyers (principals) pay water sellers (agents) at the start of the season for water delivery throughout the season. A two-part tariff contract in which the principal pays an upfront fee and then makes smaller payments throughout the growing season as water is delivered. And an output share contract in which, at the end of the season, the agent receives a share of the rice harvest as payment for water delivered throughout the season.

These observed contracts motivate a simple model of the contracting relationship in a setting where unverifiable outcomes exist and enforcement varies. The model highlights two key features that help explain the variety of groundwater contracts. First, the severity of punishment can be a limiting factor in the use of third-party enforceable contracts. When governance institutions punish contract violation severely, contracting parties can implement high powered incentives based on verifiable performance measures without having to worry about strategic uncertainty. Conversely, if punishment is weak, those institutions may be unable to credibly enforce contracts, with the result that parties must rely on repeated interactions to ensure self-enforcement. A second key feature is that the institutional environment and an individual's characteristics act in different ways on the choice of contract. Characteristics of the institutional environment influence the type of contract (relational or third-party enforced) while the specific characteristics of the contracting parties determine the form or terms of the contract. While intuitive, the empirical contracting literature has not made this distinction, primarily because of a lack of data on various contract forms arising from different contracting environments. The data and model provide this distinction and allow for new insight into how contracting decisions are made.

We draw several empirical implications from the model that we then use to guide the regression analysis. Our first set of results explores how contract form is influenced by individual characteristics such as an individual's discount rate, bargaining power, and outside option. We find that the fixed price form of the self-enforcing water contract is more likely than the two-part tariff form when seller's have valuable outside options or strong bargaining power, though there is a lack of evidence regarding the role of discount factors. Our second set of results focuses on how the type of contract is affected by severity of punishment and the quality of a signal revealing unverifiable agent action. We find that output share contracts, which rely on a verifiable performance measure, are more likely than self-enforcing water contracts (fixed price and two-part tariffs) in villages that provide severe punishment or when verifiable performance measures provide a strong signal of agent action. These findings are robust to various alternative specifications and the inclusion of household characteristics and village-level effects to control for unobserved heterogeneity.

The analysis provides three insights regarding the use of relational and formal contracts to resolve the verifiability problem in a specific empirical setting. First, there is strong empirical evidence of a strong negative relationship between the severity of punishment and the adoption of relational contracts. Intuitively, as the severity of punishment for violation decreases, breach of formal contracts becomes more attractive, limiting the size of payments that are based on the verifiable performance measure. As such, the paper contributes to the literature on the interplay between relational and formal contracts. Previous literature has focused on the inflection point where formal contracts stop supporting relational contracts and start to make relational contracting infeasible.[1] We expand the understanding of this issue by studying a setting in which there is variation in the severity of external enforcement. Thus, this paper is similar to Hermalin et al. (2013) and Antras and Foley (2015) in that it explicitly accounts for how the institutional environment shapes contract choice.

Second, there is strong empirical evidence that agents use their outside option and bargaining power to negotiate for a type of contract that leaves them with *ex post* discretion over any surplus. While bargaining clearly plays a role in the distribution of rents in any type of contract, our work highlights the importance of these individual characteristics in relational settings that create strategic uncertainty relative to settings where third-party enforcement creates no practical reason to breach the contract. This observation contributes to the empirical literature on the determinants of the specific terms or forms of contracts.[2]

Finally, we provide a theoretical model that elucidates the interaction of principal, agent, and institutions in the market for groundwater irrigation. The majority of the literature on groundwater irrigation examines market structure and tests for the existence of market power.[3] However, some studies investigate the transactional relationships within the market. These studies often uses the language of contract theory to motivate descriptive analysis of groundwater markets.[4] Although

[1]Representative papers in this literature include Baker et al. (1994, 2002), Johnson et al. (2002), Dixit (2004), Gillan et al. (2009), Desrieux et al. (2013), and Gil (2013).

[2]Previous studies examine a wide variety of determinants, including discount rates, outside options, and the cost of enforcement. There is a rapidly growing literature on the determinants of contracts in developing countries and include Banerjee and Duflo (2000), Aggarwal (2007) Bellemare (2012), Macchiavello and Morjaria (2015, 2016), Arouna et al. (2019), Bubb et al. (2018), and Macchiavello and Miquel-Florensa (2018).

[3]Examples include Shah et al. (1993), Jacoby et al. (2004), Palmer-Jones (2010), and Ansink and Houba (2012).

[4]Papers the use the language of contract theory include Kajisa and Sakurai (2005), Aggarwal (2007), and Rahman

these studies use principal-agent terminology, few have used theoretical models to ground their empirical investigation. The recent work by Giné and Jacoby (2020) proves an exception to this trend by developing a contract-theoretic model of groundwater transactions to examine the trade-off between relational and formal contracts within a given institutional environment. We go beyond their work by examining contract choice across a number of different governance institutions.[5]

2 Institutional Details

2.1 The Bangladeshi Groundwater Irrigation Market

The market for groundwater in Bangladesh is one of imperfect competition (Mukherji, 2004). Irrigation channels in Bangladesh are usually unlined and uncovered, increasing the transportation cost of water and limiting a seller's potential pool of buyers to nearest neighbors. Further limiting competition is the fragmented nature of landholding in Bangladesh. Because of cultural conventions concerning inheritance, it is rare for a household's landholding to be contiguous. Non-contiguous landholding, combined with high water transportation costs, create a market in which most water sellers are also water buyers on at least one of their parcels. The dual role of well owners as both water sellers and water buyers circumscribes market power in an economic environment of limited competition. We find that the price of water does not vary greatly within a village but, despite this, contracts for water do vary within a village.

Three key features distinguish the market for groundwater irrigation in Bangladesh from irrigation markets in more developed countries. The first is a lack of credible institutional legal authority beyond the village. The second is the difficulty for a third-party to verify the delivery of sufficient water for crop production. The third is variation across villages in the mechanism for enforcing contracts. These institutional features mean that relational contract theory is well suited to provide clarity regarding the real world environment in Bangladesh.

et al. (2011).

[5]Another study that attempts to model the behavior of buyers and sellers in the market for groundwater is by Banerji et al. (2012). Yet this work is narrowly focused on a rare contract type. Their model seeks to explain behavior in a single Indian village where the price of water is set by a council of village elders. This situation is uncommon in South Asia and unobserved in Bangladesh.

The court system that serves the rural areas of Bangladesh is not well developed, making the enforcement of contracts inconsistent and prohibitively expensive. As a result, written, legally-binding contracts are unobserved in the market for groundwater irrigation. Even if courts operated effectively, the verifiability problem in the delivery of groundwater would still exist. Water buyers determine the amount of water they will needed for the entire growing season after which water is delivered multiple times throughout the season (usually spanning 120 days). In theory, a third-party could observe each delivery of water to verify that the contracted amount was delivered. Yet, this is costly, and in practice third-party observation of water delivery is rare. In the data, only two percent of contracting parties report that a third-party observes the adequacy (volume) or the reliability (timing) of water delivery. In contrast, 95 percent of water buyers report that they observe the adequacy of water delivery while 94 percent of buyers report that they observe the reliability of water delivery. Similarly, 86 percent of water sellers report that they observe the adequacy of water delivery and 85 percent of sellers report that they observe the reliability of water delivery. This evidence suggests that there are real costs to third-party verification of water delivery and that contracting parties can use relational contracts, based on non-third-party verifiable information, to obtain welfare improving outcomes.

Within villages, extralegal institutions exist, such as councils of village elders, village headmen, and religious leaders that may be called upon to adjudicate disputes. Extralegal institutions play an important role in governing water markets both historically (Smith, 2018) and in modern South Asia (Wade, 2007), as do the social norms they are based upon (Tsusaka et al., 2015). While enforcement of contracts by village institutions is prevalent, not all villages provide such enforcement. In fact, about 45 percent of villages in the study provide no enforcement mechanism at all. This creates a contracting environment where some households can use village-level enforceable contracts while other households lack this opportunity and must rely on self-enforcing relational contracts.[6]

[6] Additional data describing the environment can be found in the Appendix.

2.2 Contracting Practices

Contracts for groundwater irrigation are for a single season, though contracting relationships span many seasons. The decision making process in securing irrigation for a parcel is sequential and begins with the principal (water buyer) choosing whether or not to grow rice during the dry *Boro* season.[7] Next, the water buyer chooses a water seller (agent) with which to contract. Once a buyer has chosen a seller, the buyer and seller negotiate over the type and terms of the contract. Contracts are agreements between a water buyer and a water seller concerning the quantity of and price for water delivery to a farmed parcel in that season. The water buyer may own a well but, due to transportation costs, chooses to purchase water for that parcel.

Three different forms of groundwater contracts are used in Bangladesh: 1) fixed price, 2) two-part tariff, and 3) output share. These three are a subset of the irrigation contracts discussed by Shah (1993) in his systematic study of groundwater markets in developing countries. The observed contracts are distinguishable from each other by variation in several different contract characteristics. Table 1 provides a summary of the various characteristics across the three forms of contracts.

In a fixed price contract the water buyer makes a one-time cash payment to the water seller at the beginning of the growing season. Prior to payment being made, both parties agree on the volume and timing of irrigation. Water is then delivered multiple times during the growing season, making it exceedingly rare for a third-party to verify that the *ex ante* agreed upon water was received. This verification problem means that fixed price contracts must rely on self-enforcement, leaving the water seller with *ex post* discretion. Once the upfront payment is made, the water buyer has no recourse in the case of breach by the seller.

In a two-part tariff contract the water buyer makes a one-time cash payment to the water seller at the beginning of the growing season for access to the seller's pump throughout the season. Once the growing season has commenced, the buyer provides payment to the seller at the time of water delivery. Since water is delivered throughout the growing season, it is rare for third parties to verify that the *ex ante* agreed upon water was received. This means that while *ex post* discretion

[7] Since 99 percent of land cultivated in the *Boro* season is allocated to rice (VDSA, 2016) the choice to plant a crop in this season implies that the crop chosen will be rice.

is balanced by the secondary payment, two-part tariff contracts must still rely on self-enforcement since the delivery of water is not third-party verifiable.

In an output share contract the water buyer agrees to pay the water seller a share of crop output at the end of the season for water delivered throughout the season. In the previous two contracts, payment is made contingent on an outcome (water delivery) that, due to its recurring delivery throughout the growing season, is costly to verify. In the output share contract, payment is contingent on crop production, which is realized once, at the end of the season. Furthermore, the rice harvest is typically milled and bagged in a communal area, allowing third parties to easily observe total production and verify that the agreed upon share of output was delivered. This makes crop production a noisy but verifiable measure of agent performance in the delivery of water. If village institutions are willing to verify payment, then output share contracts can rely on third-party enforcement and the water buyer cannot deviate from the contract terms without consequence.[8]

3 A Simple Model of Groundwater Contracting

This section presents a simple model of the contracting relationship between the water seller and water buyer. Specifically, the model highlights four main channels through which contractual form is determined: contract governance institutions, quality of an informative signal that can be used in a contract to incentivize water delivery, strategic uncertainty, and the value of outside options/bargaining power. Rather than deriving formal propositions, we highlight key empirical implications emerging from the models.

Consider a repeated contracting game between a single principal (the water buyer) and a single agent (the water seller). The repeated contracting game begins after the matching of principal and agent. In this way, the contract choice decision is sequential and separate from the matching decision. This assumption is also made by Baker et al. (1994). In each period, the agent undertakes actions related to the delivery of water, denoted as $y \in [\underline{y}, \overline{y}] \subset \mathbb{R}_+$, which is observable to both the principal and agent, but is difficult for a third-party to verify. The difficulty of verifying y is due

[8]There are a limited number of output share contracts used in villages without governance institutions. In these cases output share contracts must rely on self-enforcement, leaving the water buyer *ex post* discretion. There are only 33 such contracts, which makes up five percent of all contracts.

to the necessity of delivering water at multiple times during the growing season and the need to have third-party verifiers present at the relevant times. Thus, it is cost prohibitive for third-party enforcement of agreements that condition on y. Our assumption is empirically supported by the data.

The principal and agent can agree on a contract which promises a compensation package that is comprised of two components: a fixed payment S, and possibly a bonus payment, B that is conditioned on whether water was delivered. To model this, we assume that the agreed upon level of water is denoted by Y; thus, there is a shared understanding that the bonus (if specified in the contract) is to be paid if $y \geq Y$. Given the non-verifiability of y, the principal has discretion over the payment of the bonus. We denote the actual bonus paid by b which need not equal the promised bonus, B. The principal will have reneged on the agreement if $y \geq Y$ and yet $b < B$.

This compensation scheme is extremely general and can be adapted to represent two of the three types of informal agreements observed in Bangladesh:

- Fixed price $S > 0$ and $B = 0$.
- Two-part tariff $S > 0$ and $B > 0$.

Given the non-verifiability of y, fixed price and two-part tariffs are largely informal contracts.

Under a generic contract of the form $W = S + B$, the principal's and agent's *promised* payoffs are $V = r(Y) - S - B$ and $U = S + B - c(Y)$ where $r(Y)$ is the principal's revenue function and $c(Y)$ is the agent's cost function. We assume both $r(Y)$ and $c(Y)$ are differentiable such that $r'(Y) > 0$, $r''(Y) \leq 0$, $c'(Y) > 0$ and $c''(Y) \geq 0$. The reservation payoffs for the principal and agent are $\overline{v}$ and $\overline{u}$, respectively. Note that *actual* payoffs are obtained by replacing Y, S, and B with y, s, and b in the payoff functions.

3.1 Optimal Relational Contracting

To solve for the optimal relational contract, consider the stage-game timeline, which follows the typical principal-agent sequence:

1. Principal (buyer) offers a contract–a price/bonus/quality triplicate, (S, B, Y).

2. The agent (seller) accepts or rejects. If rejected, the parties receive their reservation payoffs.

3. If accepted, the agent chooses actual water volume, y.

4. The principal observes y and chooses actual bonus b. The promised fixed payment, S, is also made.

The above stage game is repeated indefinitely between the principal and the agent. Moreover, the relational contract is self-enforcing if it describes a subgame perfect equilibrium of the infinitely repeated game. Levin (2003) shows that there exist stationary contracts that are optimal in that the same (optimal) contract is offered in every period, t. If δ is the common discount factor, then multiplying the payoffs by $1-\delta$ expresses the present value in terms of per-period averages. The principal's contract design problem is:

$$\max_{(Y,S,B)} \quad (1-\delta)\left[r(Y)-S-B\right]+\delta V(C), \tag{1}$$

$$\text{s.t.} \quad (1-\delta)\left[r(Y)-S-B\right]+\delta V(C) \geq \overline{v}, \tag{2}$$

$$(1-\delta)\left[S+B-c(Y)\right]+\delta U(C) \geq \overline{u}, \tag{3}$$

$$(1-\delta)\left[r(Y)-S-B\right]+\delta V(C) \geq (1-\delta)\left[r(Y)-S\right]+\delta\overline{v}, \tag{4}$$

$$(1-\delta)\left[S+B-c(Y)\right]+\delta U(C) \geq (1-\delta)\left[S-c(\underline{y})\right]+\delta\overline{u}. \tag{5}$$

Constraints (2) and (3) are the individual rationality (IR) constraints and (4) and (5) are the self-enforcement (SE) constraints. $V(C)$ and $U(C)$ are the continuation payoffs under cooperation; i.e. when both parties have honored their obligations under the agreement. Under the assumption of stationarity, the same contract is offered every period, t, so the above contract design problem becomes essentially a static optimization problem. It is well known from the relational contracting literature that the solution to the above constrained optimization yields an optimal relational contract.

MacLeod and Malcomson (1989) find that the form of the optimal relational contract can range from fixed price contracts to discretionary bonus contracts. Within the context of our model, the exact form of the optimal contract can depend on several factors, which might be important for predicting when we might observe, say, fixed price contracts rather than two-part tariffs or vice versa. An analysis of the constraints in the optimization problem can provide some clues about the optimal contractual form and guidance for our econometric analysis.

3.1.1 Empirical Implications: Water Contracts

In assessing the constraints of the relational contracting model, there are two obvious channels through which contractual form can be impacted. First, strategic uncertainty potentially plays an important role in shaping contractual form. Second, the relative share of rents captured by each party can affect the form of the contract. Rent share is driven by a combination of the availability of outside options and bargaining power.[9]

We first discuss the potential impact of strategic uncertainty. Papers by Dal Bó and Fréchette (2011, 2018) suggest that strategic uncertainty is important in influencing the degree of cooperation in repeated games. Since relational contracts are a type of repeated game, it would not be surprising if the allocation of strategic uncertainty via contractual form can affect outcomes. Strategic uncertainty typically focuses on how much loss a party might suffer when that party attempts to cooperate but the other party shirks. Analogously in a contracting framework, strategic uncertainty arises when one party bears the costs of fulfilling his/her end of the agreement but the other party does not. Depending on the timing of moves, if the counter-party shirks, it can leaving the honoring party with large losses. For example, fixed price contracts impose more strategic uncertainty on the buyer than two-part tariffs because once the buyer makes the upfront payment, the buyer is at the mercy of the seller who has all of the *ex post* discretion to deliver or not. In the two-part tariff, some of the losses are controlled since the buyer does not pay in full until there is delivery.

More broadly, strategic uncertainty can be transferred from principal to agent (or vice versa) through the specification of S and B in the contract. For example, if S is relatively high in that

[9] According to Muthoo (1999), the outside option principle suggests that if a party has an outside option that promises a payoff that exceeds the share of surplus that would have been obtained under, say, Nash bargaining, then the party will receive a share that matches the amount obtained from the outside option. Thus, the presence of an outside option potentially drives up the share of surplus received. On the other hand, if the outside option is relatively low so that it does not promise a payoff that exceeds what would have been attained under bargaining, then the outside option has no impact on surplus distribution.

$S > \overline{u} + c(\underline{y})$, then the agent is assured of at least his reservation payoffs even if the principal does not honor B. On the other hand, the principal would realize profit that falls below her reservation payoff of $\overline{v}$ if the agent shirked and chose $y = \underline{y}$. Hence, when there is mutual shirking, the agent is still better off than if no contract were agreed upon whereas the principal would be worse off. In other words, the principal can never be made "whole" in the event of breach without third-party intervention. Generally speaking, the principal can reduce the agent's exposure to strategic uncertainty by raising S and lowering B. The cost, however, is that the principal takes on more strategic uncertainty herself.

Blonski et al. (2011) propose that cooperation under strategic uncertainty requires a higher discount factor that exceeds the standard discount factor needed for cooperation in the absence of strategic uncertainty. In other words, a sufficiently high discount factor can mitigate concerns about strategic uncertainty to induce cooperation. Thus, the discount factor can proxy for the degree of strategic uncertainty in the contract.

Empirical Implication 1. *All else equal, the frequency of fixed price contracts relative to two-part tariffs should increase with the buyer's discount factor.*

We now discuss the impact of surplus share on contracting form. Combining the two self-enforcement constraints (5) and (4) yields:

$$\frac{\delta}{1-\delta}[V(C) - \overline{v}] \geq B \geq c(Y) - c(\underline{y}) - \frac{\delta}{1-\delta}[U(C) - \overline{u}]. \tag{6}$$

One can immediately see that, in order to be self-enforcing and therefore credible, the size of the promised discretionary payment must be bounded above by the discounted future rents to the principal. However, if the principal makes no rents, then the only credible contract is a fixed price contract. Even with a zero bonus, such a contract can still ensure that the agent delivers sufficient water so long as the right hand side of (6) is non-positive, which is possible if the discount factor is sufficiently high given that all the rents go to the agent.

According to the outside option principle, such a scenario is most likely to prevail in cases where the agent has a valuable outside option or relatively high bargaining power. Recall that the outside option principle states that if the expected payoff from the outside option exceeds the share of surplus obtained from the transaction, then the party with the outside option will receive a share that ensures that their expected payoff from the transaction matches the outside option payoff. Thus, the presence of an outside option potentially drives up the share of surplus received by the agent. We say "potentially" because, under the outside option principle, the agent's surplus share is only weakly increasing in the presence of an outside option. If the payoff from the outside option is lower then the payoff obtained from the transaction, then the outside option will have no impact on the nature of the water contract. Thus, we would expect some interaction between bargaining power and the agent's outside option.

Empirical Implication 2. *All else equal, the frequency of fixed price contracts relative to two-part tariffs should increase if the seller has a valuable outside option and/or strong bargaining power.*

3.2 Output Share Contract

We now turn to the output share contract, which in the Bangladesh ground water irrigation context, is of the form $S = 0$ and $\xi \in [0, 1]$ where ξ denotes a share of crop output q. Because q is realized only once, at the end of the growing season, as opposed to reoccurring throughout the season, it is much less costly for a third-party to verify. The cost of verification is further reduced by the fact that the crop, rice, is usually processed in a communal area. Given the lower cost of verifying crop output versus water delivery, we assume that it is much easier to structure a third-party enforceable contract around q rather than y.

When contracting with a water seller, the primary consideration for a buyer is to ensure sufficient water delivery. When water is not verifiable, the principal-agent literature suggests that a credible measure of whether water was delivered can be useful for structuring a contract. Thus, a contract based around q can be used to incentivize y so long as there is sufficient correlation between the two. The downside, however, is that the relationship between q and y is stochastic. Thus, a high q does not necessarily measure failure to deliver y and vice versa. This noise can introduce additional complications related to optimal risk sharing, but we focus on how this noise impacts the efficacy of the output share contracts in incentivizing y.[10]

For simplicity, we assume that q is binary valued so that $q \in \{0, q_g\}$. Moreover, let $f(y) = Prob\{q = q_g|y\}$ and $1 - f(y) = Prob\{q = 0|y\}$. We also assume that $f'(y) > 0$ and $f''(y) \leq 0$. These assumptions, combined with the agent's convex cost function, implies that the well-known first-order approach can be used in setting up the incentive compatibility constraint in the contract design problem (Rogerson, 1985). The form of the output share contract is $W = \xi q$ so that total payment, W, to the agent depends on a successful crop season and the share coefficient ξ. The agent's expected payoff is $E(U) = f(y)\xi q - c(y)$ and the principal's profit is $E(V) = r(y) - f(y)\xi q$.[11]

One of the appealing features of output share contracts is that, when institutions for third-party enforcement exist and punishment for contract breach is sufficient, then the parties can structure a third-party enforced contract around q. Thus, parties do not have to rely on self-enforcement or repeat trading to ensure contract compliance. As such, third-party enforced contracts reduce the strategic uncertainty that is associated with repeated games. However, the trade-off is that the relationship between crop output, q, and water, y is now noisy and this noise can impact the relative efficacy of the crop share contract in inducing adequate and reliable water delivery from the seller.

In order to generate empirical implications, we begin by setting up the optimal output share contract design problem. The optimal contract is one where, for a given y, the principal minimizes the cost of implementing that y.[12]

[10] While risk sharing is a potential consideration, it largely affects the strength of optimal incentives rather than the qualitative predictions about incentives and performance. Since we are not calibrating a structural model, but instead focusing on qualitative predictions about contractual form, we avoided the complexity of specifying risk preferences in our model.

[11] While one can argue that the principal's revenue should be a function of q instead of y as high crop yield is her ultimate goal, keep in mind that the contract is for water with a water selling agent. Output is ultimately affected by other factors besides just water and the principal may contract out for other services that affect q. Within the context of water contracting, q is simply a convenient verifiable signal of water delivery that can be used to incentivize the agent. One can think of $r(y)$ as the value of the water to the principal.

[12] One can also setup an optimization problem that maximizes profit over y and ξ. However, our study focuses on contractual form rather than optimal water level purchases. Hence, the minimization problem yields the optimal contractual form in a simpler framework.

$$\min_{\xi} \quad f(y)\xi q, \tag{7}$$

$$\text{s.t.} \quad f(y)\xi q - c(y) \geq \overline{u}, \tag{8}$$

$$f'(y)\xi q - c'(y) \geq 0, \tag{9}$$

where (8) is the agent's participation constraint and (9) is the agent's incentive compatibility constraint. The problem is linear in ξ which suggests that the solution can be obtained by choosing the minimum ξ that obeys the constraints. Note that by (9), we have:

$$\xi \geq \frac{c'(y)}{f'(y)q}. \tag{10}$$

Moreover, by (8) we require:

$$\xi \geq \frac{\overline{u} + c(y)}{f(y)q}. \tag{11}$$

Hence, the optimal share rate is:

$$\xi = \min\{\frac{c'(y)}{f'(y)q}, \frac{\overline{u} + c(y)}{f(y)q}\}. \tag{12}$$

The above can be substituted into the principal's objective function $f(y)\xi q$ to obtain the optimized incentive cost function:

$$C^I(y) = f(y)q \min\{\frac{c'(y)}{f'(y)q}, \frac{\overline{u} + c(y)}{f(y)q}\} = \min\{\frac{f(y)}{f'(y)}c'(y), \overline{u} + c(y)\}. \tag{13}$$

The incentive cost function is the principal's "cost" of contracting with the agent to obtain water. Note that the principal does not produce water; she purchases water from the agent so her cost is the cost of structuring an incentive contract with the agent, which in this case, is an output share contract. Thus, (13) is the minimum cost of sourcing y amount of water from the agent. The principal's profit is:

$$V = r(y) - \min\{\frac{f(y)}{f'(y)}c'(y), \overline{u} + c(y)\}. \tag{14}$$

3.2.1 Empirical Implications: Output Share Contracts

The output share model provides intuition into the contracting decision. We focus on two insights that arise from the contracting environment in the Bangladeshi groundwater irrigation market. First, the noisiness of the relationship between q and y plays an important role in determining the value of the contract. Second, the availability of governance institutions and the severity of third-party enforcement can affect the type of contract chosen.

With regard to the noisiness of the relationship between q and y, we focus on the marginal impact of water on the probability of successful crop yield. This can be encapsulated by $f'(y)$. Note that if the relationship between q and y was completely random, then $f'(y) = 0$. If the relationship between q and y is not completely random, then an increase in $f'(y)$ makes the output share contract more profitable because, by (12), the optimal share rate is weakly decreasing in $f'(y)$. Thus, if water has a larger impact on the probability of a successful crop yield, then the principal optimally allocates a smaller share to the agent to induce adequate and reliable water delivery. Additionally, by (13), the incentive cost to the principal is weakly decreasing in $f'(y)$, which means that the principal's profit is weakly increasing in $f'(y)$. Overall, the increase in the principal's profits as $f'(y)$ increases means that output share contracts are more likely to be used.

Empirical Implication 3. *All else equal, the number of output share contracts relative to water contracts (fixed price or two-part tariffs) should increase with the informativeness of a signal regarding the noisiness of the relationship between water input and crop output.*

In the absence of governance institutions to punish contract breach, output share contracts are only credible if they are self-enforcing; i.e. if they are relational contracts. The self-enforcement constraint would have to ensure that the principal will deliver the promised crop share payment to the agent at the end of the season. This constraint can be written as:

$$\frac{\delta}{1-\delta}[V(C) - \overline{v}] \geq \xi q. \tag{15}$$

The problem with relational contracts based on output share is that they expose the parties to both strategic uncertainty and noise between q and y while offering no obvious benefits over a relational contract directly for water. To see this, note that, by (12), the optimal share rate is sensitive to the magnitude of $f'(y)$. Specifically, when $f'(y)$ is small, ξ is high which puts pressure on the self-enforcement constraint making self-enforcement more difficult. Thus, with noise, it is harder to achieve self-enforcement. Hence, output share contracts should be observed less frequently when third-party enforcement is not available.

When institutions are available for contract enforcement, the output share contract is more appealing relative to the water contracts because q is easier for a third-party to verify than y for reasons stated earlier. However, third-party enforcement is only effective if the punishment for breach is sufficiently high. As such, in environments that are characterized by the availability of governance institutions, adequate punishment for breach of contract should make output share contracts more prevalent because they eliminate the strategic uncertainty associated with informal relational contracts.

Empirical Implication 4. *All else equal, the number of output share contracts relative to water contracts (fixed price or two-part tariffs for water) should increase with the availability of harsher punishments for contract breach.*

4 Data and Descriptive Evidence

To document patterns of how different contracts are used to purchase groundwater for irrigation and to test the implications of the model, we employ data on 960 households from 96 villages. These households were surveyed immediately after the 2013 *Boro* season to collect information on contracts used in that season. A village-level survey collected information on village-level governance institutions and sanctions for contract violations. Households and villages were randomly selected while *upazilas* (counties) were selected using a weighted random sampling method to ensure a representative sample of irrigated agriculture in Bangladesh. The subsequent analysis relies on the 707 households in the survey that purchased irrigation for their largest parcel in the 2013

Boro, or dry, season.

4.1 Discount Rate

A central feature of relational contracts is that they rely on repeat trading for enforcement (Corts and Singh, 2004; Macchiavello and Morjaria, 2015). The degree to which relational contracts are self-enforcing is therefore dependent on how much strategic uncertainty exists in the relationship. As Blonski et al. (2011) point out, a sufficiently high discount rate can reduce concerns about strategic uncertainty and facilitate repeat trading. Our data contains information on water buyers' discount rate coming from a simple choice experiment involving intertemporal trade-offs designed to measure subjective interest rates.[13]

Panel A of Table 2 summarizes data on water buyers' discount rate for each contract type by whether or not villages provide third-party enforcement of contracts. Mean discount rates do not vary much across enforcement environments, which is to be expected. This is because water contracts must be self-enforcing regardless of whether third-party enforcement exists for output share contracts. Furthermore, since formal output share contracts do not rely on repeated trading, there is no reason to assume the discount rate would vary for these contracts across environments. What is surprising, given our first empirical implication, is that we do not see much variation in mean discount rate between fixed price and two-part tariff contracts. Recall that Empirical Implication 1 states that the frequency of fixed charge contracts should be increasing in the discount rate.

Because simple summary statistics may hide underlying differences in distributions, we plot the kernel density of the discount rate for water contracts (see Figure 1). We focus on contracts in villages that do not provide enforcement since contracting in an environment where formal contracts can serve as fall back options to relational contracts may reduce, on its own, strategic uncertainty in relational contracts. Visually there appears to be differences between discount rates for those using fixed price compared to two-part tariff contracts. However, a two-sample Kolmogorov-Smirnov test fails to reject the null of the equality of distributions. Because of this, we cannot conclude that

[13] See the Appendix for information regarding the choice experiment.

there is any descriptive evidence supporting the first empirical implication from our model.

4.2 Outside Option/Bargaining Power

The second empirical implication of the model states that fixed price contracts, in which the seller retains *ex post* discretion, will be more frequent when the seller receives all of the rents, which is more likely when the seller has an outside option and/or more bargaining power. To proxy for the value of the seller's outside options, we use a binary measure of whether or not the water seller has alternative buyers who could purchase water in the case that the current contracting relationship broke down. The variable takes a value of one if alternative buyers exist. In terms of bargaining power, the survey contains a number of different questions regarding the power dynamics between buyer and seller. Water buying households were asked if the water seller is a leader in the village, if the seller's social rank is higher, and if the seller can harass the buyer with impunity were the buyer to complain about the contract. We aggregate these into a variable for the seller's relative bargaining power that takes a one if the buyer responded "yes" to any of these questions.

Panel B of Table 2 presents data on contract choice by outside option. In villages that do not provide third-party enforcement, there is an overall preference for fixed price contracts. However, there is wide variation in the rates of adoption of each contract depending on whether or not the water seller has outside options. Over 90 percent of fixed price contract use occurs when a valuable outside option exists, while 88 percent of two-part tariff contracts occur when no outside option exists. In villages that provide third-party enforcement of formal contracts, there is also an overall preference for fixed price contracts compared to other forms of contracts. Tabulating the rate of adoption for each contract form, based on the existence or absence of outside options, there is little overall shift in preferences. Each contract is used about 85 percent of the time when no outside option exists and 15 percent of the time when an outside option exists. In villages that provide third-party enforcement, the existence or absence of an outside option appears to have no influence on the form of the contract chosen by parties.

Panel C of Table 2 presents data on contract choice by seller's bargaining power. In villages where all contracts must be self-enforcing, sellers with bargaining power tend to use fixed price contracts. Not only do a majority of fixed price contracts in these villages occur when the seller has the bargaining power (54%) but a majority of all contracts are fixed price contracts (56%) when the seller has bargaining power. Conversely, when the seller lacks bargaining power, two-part tariff and output share contracts, which either balance *ex post* discretion or give it to the buyer, are much more common. A similar relationship exists between bargaining power and contract form in villages with and without third-party enforcement.

Intuitively, outside options should not play much of a role in contracting environments where formal contracts exist since there is no practical reason to breach the contract. Even if parties use self-enforcing contracts, third-party enforceable contracts are available as a fall back option. Panel A of Figure 2 presents evidence to support this intuition. When relational contracting is the only option, water sellers appear to use the existence of an outside option as leverage to secure fixed price contracts in which they retain *ex post* discretion. When outside options do not exist, the parties settle on two-part tariff contracts, which balance the *ex post* discretion of the two parties. Compare this to the evidence in Panel B of Figure 2. In settings where formal output share contracts are possible, there is little variation in contract adoption rates based on the existence of an outside option.

While the outside option should only play a role in environments where third-party enforceable contracts cannot serve as a fallback, the same is not true of bargaining power. Panel C and D of Figure 2 graph the relative frequency with which each relational water contract is used based on who has the bargaining power. When sellers have bargaining power, fixed price contracts are much more frequent, accounting for two-thirds of the contracts, regardless of the enforcement environment. In contrast, when sellers lack bargaining power, fixed price contracts make up less than half of the contracts, again regardless of the environment. While such descriptive evidence is far from definitive, the empirical patterns in the data lend tentative support to the empirical implications derived from our model of groundwater contracts.

4.3 Informative Signal

The third implication of the model is that the frequency of output share contracts will be increasing in the strength of an informative signal. One potential credible signal that is easily observable to both parties is soil quality. The data contain information on the soil quality of irrigated parcels in the form of color, consistency, and texture. We aggregate this information into a simple ranking of soil as either poor, good, or excellent. Examining the data, a clear pattern exists in the distribution of soil quality in regards to the types of contracts used to secure groundwater irrigation (see Panel A in Table 3). For parcels farmed by households using either of the water contracts, the distributions of soil quality is relatively normal. In contrast, the distribution of soil quality for parcels farmed by households using output share contracts is skewed towards excellent quality soil.

An obvious reason for this relationship is that since groundwater irrigation is an input into crop production, and output share contracts are contingent on crop production, the quality of the soil will partially determine the value of the contract to the water seller. A more subtle intuition behind this relationship is that soil quality is operating as an informative signal regarding the relationship between water input and crop output. When soil quality is extremely poor, crop output is likely to be a poor performance measure of whether or not the agreed upon amount of water was delivered. The appropriate amount of water may be delivered but, because of sandy or alkaline soil, crop output is low. As soil quality increases, however, the accuracy of crop output as a performance measure of agent action improves. Soil quality is an informative signal regarding the accuracy of crop output as a measure of water delivery.

If soil quality is operating as an informative signal, then one should find evidence that better quality soil reduces the variance in crop production. To verify this, we conduct regressions of crop output on inputs using a parsimonious yield function, with indicator variables for soil type.[14] Regression results confirm that better quality soil increases output. However, what we are really interested in is if better quality soil reduces the variance or noise in crop output. To determine this, we square the residuals from those regressions and compare the mean of the residuals across soil types (see Panel B of Table 3). Not only does better soil increase yield but better soil reduces

[14] Regression results are presented in Table A4 and A5 in the Appendix along with an extended discussion of soil quality in the data and its role as an informative signal.

the variance of yield.[15] Figure 3 graphs the squared residuals, which when they come from parcels with excellent soil are closer to zero than squared residuals from parcels with poor soil. Squared residuals from parcels with good soil tend to fall between these two extremes. This evidence provides conditional support for the empirical implication that a more informative signal is associated with output share contracts.

4.4 Village-Level Punishment

Villages can be broadly categorized as those that provide enforcement of formal contracts and those that do not. Among villages that provide enforcement, there are several varieties of governance institutions. Some villages rely on a single individual, often a relative, trusted friend, or religious leader, to enforce contracts. The disputants appeal to this individual who then arbitrates the dispute and determines punishment. Other villages rely on a group of village elders or community leaders to enforce contracts. The elders together discuss and rule on the dispute. A small set of villages rely on the official court system to enforce contracts.

In addition to variation in the type of governance institution, villages also differ in what types of punishments are used by each institution. Using data collected at the village-level, we categorize these into three types of punishment, ranked from least severe to most severe.[16] The least severe punishment is when the governance institution devolves responsibility for determining punishment to the disputants. These punishments are determined through bi-partisan negotiation, and are most often not enforceable, making them relatively mild. This private form of punishment is uncommon, occurring in only seven villages. More severe than privately determined punishment is economic punishment, most often in the form of a monetary or in-kind fine. This type of punishment is most commonly used when a trusted individual or a court is arbitrating the dispute. The most severe form of punishment observed in rural Bangladesh is social ostracism. This punishment

[15] We conduct a Mann-Whitney test for equality of means across each pair. The test rejects the null of equality between squared residuals for poor soil quality and excellent soil quality at the 90 percent level. Results are stronger when we use a t-test.

[16] The data contain both household and village-level information on contract enforcement and punishment. Given that not all households have experienced contract violation, we use the village-level data on enforcement and punishment. In each village a focus group discussion was conducted with seven to ten village members to determine what institutions exist to enforce contracts and what types of punishments are used by those institutions when contracts are violated.

is generally imposed by village elders and can take the form of reduced access to community subsidized mechanical devices (i.e., hullers, etc), trade embargoes, or exclusion from social and religious activities. Given the small and stable nature of rural communities in Bangladesh, this type of punishment is more severe to a household than monetary fines, even if these fines are levied by a court. Panel A in Table 4 presents the frequency with which each of these methods of punishment are utilized by each governance institution.

A clear empirical pattern emerges from a descriptive analysis of the village-level data and how it relates to household-level contract choice. Households that live in villages which use more severe punishment in the resolution of contract disputes tend to use output share contracts (see Panel B in Table 4). While only 22 percent of output share contracts are used in villages with no third-party enforcement over half (56 percent) of output share contracts are used in villages that employ social ostracism to enforce contracts. Conversely, nearly half of the fixed price and two-part tariff contracts are used in villages that provide no contract enforcement, while these contracts are used only around 16 percent of the time in villages that utilize social ostracism. Figure 4 displays the number of relational water contracts and formal output share contracts used within villages utilizing each of the three different types of punishment. The frequency of water contracts is much higher in villages that provide weak (private resolution) punishment while output share contracts are much more common in villages that provide severe (social ostracism) punishment. This stylized fact - that formal output share contracts are more likely in villages that punish contract violation severely - is a key implication in the theoretical model.

4.5 Additional Data Considerations

Because the choice of contract may also be influenced by the type of the well that irrigates the parcel and the ability of the seller, we control for well/project characteristics (see Table 5). We include an indicator variable for the type of well. The majority of wells in the sample (85 percent) are shallow tubewells while the remaining 15 percent are deep tubewells. Shallow tubewells tend to be owned by individuals while deep tubewells tend to be owned by groups of individuals. Negotiating over contracts with a group instead of an individual may influence contract choice (Gil and Zanarone, 2017). Deep tubewells have larger command areas and provide water to more buyers than shallow tubewells. This could increase competition for water, making contract violation more likely and therefore making third-party enforceable contracts more common with deep tubewells. In addition to the type of well used, we include the horsepower of the pump, the depth of the water table, and the time in minutes it takes to irrigate a decimal of land (40.46 m^2). All three of these well characteristics affect the cost of delivering water and therefore may be related to contract choice. Pumps with lower horsepower, that draw from deeper water tables, or take longer to irrigate a given area may make agent action more costly, reducing the value of the self-enforcing contracts, and making defection more likely. We also include the linear distance between the well and the irrigated plot, since proximity between these two points is a key determinant in a buyer's choice of seller. Finally, the seller's reputation for completing a job and the buyer's previous relationship with the seller may influence the choice of seller. To control for this, we include a binary indicator equal to one if the water seller has a reputation as being trustworthy and variable equal to one if parties are related to each other or of the same social caste.

5 Econometric Framework

Our simple model of groundwater contracting yields several testable empirical implications. Implications 1 and 2 make predictions regarding the choice among forms of water contracts while Implications 3 and 4 make predictions regarding the choice between water contracts and output share contracts. As such, we define two basic econometric specifications and then discuss details of our identification strategy.

5.1 Empirical Specifications

To test the first two implications, we estimate:

$$R_{ij} = \alpha_0 + \alpha_1 D_{ij} + \alpha_2 O_{ij} + \alpha_3 N_{ij} + \alpha_4 (O_{ij} \times N_{ij}) + \mathbf{W}_{ij}\gamma + \nu_{ij}, \tag{16}$$

where the dependent variable is a binary indicator that equals one if household i in village j uses a fixed price contract and zero if it uses a two-part tariff contract. D_{ij} measures the buyer's subjective discount factor, O_{ij} is a dummy equal to one if the seller has an outside option, and N_{ij} is a dummy equal to one if the seller has greater bargaining power than the buyer in contract negotiation. Also included are a set of well/project characteristics ($\mathbf{W}$). We allow for a composite error term, $\nu_{ij} = \epsilon_{ij} + v_j$ made up of an idiosyncratic household term (ϵ_{ij}) and an unobserved village-level heterogeneity term (v_j) that may be correlated with household characteristics.

To test the next two implications, we estimate:

$$C_{ij} = \beta_0 + \beta_1 P_j + \beta_2 K_{ij} + \mathbf{W}_{ij}\gamma + \nu_{ij}, \tag{17}$$

where the dependent variable is a binary indicator that equals one if household i in village j uses an output share contract and zero if it uses a water contract (either fixed price or two-part tariff). P_j measures the severity of punishment used in village j when formal contracts are violated while K_{ij} measures the accuracy of the informative signal. Again, we control for well/project characteristics ($\mathbf{W}$) and allow for a composite error term containing unobserved village-level heterogeneity.

5.2 Identification Strategy

Before discussing the identification strategy, it is useful to reflect upon the characteristics of an ideal data set for causal identification. Ideal data would be either derived experimentally or be cross-sectional with multiple observations over time. While experimental data provides the cleanest possible identification, the social and institutional environment in rural Bangladesh makes it difficult (if not impossible) to randomly assign village governance institutions. Alternatively, panel data would allow for the inclusion of household or relationship fixed effects but there is no guarantee that there would be variation in the contracts chosen by households and it is highly unlikely that there would be any variation in village-level institutions, which change extremely slowly over time. Thus, it is not clear that experimental or panel data would prove adequate to the empirical task at hand.

Although clean identification is difficult with cross-sectional data there are unique aspects to Bangladesh's groundwater irrigation market that reduce the potential for endogeneity. One aspect is that the matching of buyer and seller is not endogenous to the contract choice equation. As Ackerberg and Botticini (2002) point out, non-random matching between contracting parties may lead to endogeneity in the contract choice equation, though as Corts and Singh (2004) argue, this is not a given. While non-random matching surely exists between contracting parties in the data, there is no evidence that the choice of contract is a determinant of the contracting partner. Rather, matching of buyer and seller appears to be solely a function of proximity and reputation, both of which we are able to directly control for. In the data, 53 percent of water buyers responded that the most important factor in choosing a water seller was the proximity of the seller's well to the buyer's parcel. The remaining 47 percent responded that a seller's reputation or the buyer's previous relationship with the seller was the most important factor in choosing a water seller. No buyer responded that the ability to select a particular type of contract was an important factor in their choice of seller.[17]

A second unique aspect is that many of the contract interlinkages discussed in the development literature are not present in the Bangladeshi groundwater irrigation market. The most common contracts in agrarian contexts are landlord-tenant relationships and the giving and receiving of loans (Basu, 1990; Wood and Palmer-Jones, 1991; Shah, 1993; Hayami and Otsuka, 1993). In the data, only four percent of water-buying households purchase water from their landlord. Similarly, only four percent of water-buying households receive loans from the water seller while two percent provide loans to the water seller. Thus, the typical contract interlinkages are not common in the data set and we exclude them from the regression. We do however, follow Bellemare (2012, 2013) by directly controlling for a set of variables that account for the matching of water buyer and water seller, such as reputation, caste, kinship, and the specific characteristics of the well.

These unique aspects of the groundwater irrigation market do not completely eliminate the potential for bias, especially bias resulting from unobserved heterogeneity at the village-level, confounding identification of the causal effect of enforcement on contract choice. A straightforward

[17] In the survey, the respondent was asked to rank, in order of importance, the determinants in their choice of water seller. Options included 1) good existing relationship with water seller, 2) water seller has a good reputation, 3) water seller will allow me to choose the terms of the contract (not including price) that I prefer, 4) water seller offers the best price (due to proximity of well/parcel), 5) water seller offers the best price (by guaranteeing discounts if seller is unable to provide irrigation), 6) the number of alternative water sellers is limited.

solution is to include village-level fixed effects, which we implement when estimating equation (16). However, when we want to identify the impact of village-level punishment, as in equation (17), including village-level fixed effects would create perfect collinearity with our variable of interest, which is measured at the village-level. As an alternative, we adopt a Mundlak (1978)-Chamberlain (1984) device as discussed in Papke and Wooldridge (2008). The intuition is that, similar to Aggarwal (2007), the data can be viewed as a quasi-panel with multiple observations per village over households instead of the traditional panel structure of multiple observations per household over time. This implies that household-level observations are, within villages, not *i.i.d.* Thus standard errors are clustered at the village-level to account for correlated errors within the village. Consistent with Mundlak (1978) and Chamberlain (1984), we assume that the unobserved effect can be replaced with its projection onto the village averages of all household-level variables. Including these averages in the regression as additional explanatory variables controls for the unobserved village-level heterogeneity and allows us to generate consistent and unbiased point estimates. Conditional on these controls for the contracting environment, we can identify the impacts of the discount rate, outside options, bargaining power, soil quality, and village-level punishment on contract choice.

6 Econometric Evidence

6.1 Discount Rate

The first empirical implication from the model states that the frequency of fixed price contracts relative to two-part tariff contracts should increase with the buyer's discount rate. The initial evidence for this relationship in the data was weak at best, with both Table 2 and Figure 1 showing small but statistically insignificant differences in discount rates across the two types of water contracts.

Table 6 presents a more rigorous test of Empirical Implication 1. We report coefficient estimates from linear probability models regarding the effect of the buyer's discount rate on the likelihood that a household adopts a fixed price contract. In addition to testing the empirical implication regarding discount rate, the regressions also include variables that allow us to test Empirical Implication 2.

The data for these regressions are limited to only fixed price and two-part tariff contracts, excluding output share contracts, in order to allow for a cleaner test of the optimal water contracting model. Columns (1) and (2) exclude village-level effects, columns (3) and (4) control for village-level unobservables using the Mundlak-Chamberlain device, and columns (5) and (6) use village-level fixed effects as controls. All regressions include our standard set of project/well characteristics, though coefficients on these variables are not reported. Even numbered columns include an interaction term between outside option and bargaining power while this interaction term is excluded in odd numbered columns.

Result 1. *There is no econometric evidence in support of Empirical Implication 1, that an increase in the buyer's discount rate increases the probability of adopting fixed price contracts.*

Though heterogeneity exists in individual discount rates, higher discount rates do not increase the probability of a fixed charge contract being chosen. A lack of empirical evidence for the first implication from out model is clearly disappointing, though it is not terribly surprising given the numerous issues in eliciting individual, subjective discount rates (Anderson et al., 2006, 2008).[18]

While we do not find evidence supporting the first empirical implication, it is important to remember that failure to reject the null cannot be interpreted as evidence in support of the null. Rather, we interpret this non-result as evidence of our own failure to adequately and precisely elicit individual discount rates in the field. In retrospect, there were several potential flaws in our choice experiment. First, our choice of range for interest rates (10 to 55 percent) was likely two narrow, given that surveyed households reported paying, on average, interest rates of 52 percent. This caused pooling at the top end of the range. Second, our choice of measuring rates at five percent intervals may have been too broad, meaning we cannot distinguish small but potentially important variation within any given interval. Finally, unlike choice experiments in the lab, many choice experiments in the field, including ours, do not pay households for their participation or conditional on their responses. This means that our experiment was not incentive compatible. Thus, households may have paid insufficient attention to the choice experiment, resulting in noisy data. For all these reasons, we believe it is appropriate to interpret the null result regarding

[18]See the Appendix for a more detailed discussion of these issues.

Empirical Implication 1 as a failure in our ability to collect sufficiently precise data and not a rejection of the theoretical model.

6.2 Outside Option/Bargaining Power

Empirical Implication 2 concerns the role of the agent's outside option and/or bargaining power in the choice of water contracts. From the outside option principle, having a valuable outside option or strong bargaining power potentially drives up the share of surplus received by the seller. However, the agent's share of surplus is only weakly increasing in the outside option, meaning one should expect some interaction between bargaining power and the outside option. Table 2 and Figure 2 present evidence that the presences of an outside option for the seller and relatively high bargaining power for the seller are associated with the choice of fixed price contracts in which the seller retains *ex post* discretion over any surplus.

Table 6 presents results from regressions designed to elucidate how the seller's outside option, the seller's bargaining power, and their interaction influence the choice between types of water contracts. Columns (1), (3), and (5) report results from simple regressions without an interaction term, while columns (2), (4), and (6) include an interaction effect.

Result 2. *There is strong and consistent support for Empirical Implication 2, that the number of fixed charge contracts relative to two-part tariff contracts increases when the seller has an outside option and/or strong bargaining power.*

The coefficients on both the indicator for if the seller has an outside option and the indicator for if the seller has bargaining power are positive and significant. The frequency of fixed price contracts, relative to two-part tariff contracts, is higher when sellers have outside options but no bargaining power. The frequency of fixed price contracts also increases when sellers have bargaining power but no outside option. These results are robust to the inclusion of the Mundlak-Chamberlain device, village fixed effects, and interaction terms. Sellers with outside options but weak bargaining power are between 35 to 45 percent more likely to adopt fixed price contracts. Meanwhile, sellers with strong bargaining power but no outside option are between eight and 16 percent more likely to adopt fixed price contracts.

Additionally, the impact of bargaining power or the outside option declines in the presence of the other, just as the outside option principle suggests. In our data, bargaining power no longer matters when the outside option is high but the reverse is not true. Outside options still increase the frequency of fixed price contracts even in the presence of bargaining power, just not as substantially as they do when sellers must rely on their outside option alone (around 30 percent as opposed to around 40 percent). The econometric results provide consistent evidence that sellers with strong bargaining positions, either due to the existence of alternative buyers or to a relatively powerful social position in the community, are able to use that power to obtain relational water contracts in which they retain *ex post* discretion to deviate in the terms of the contract.

6.3 Informative Signal

One of the attractive features of output share contracts is that they are third-party enforceable. However, since crop output is a noisy measure of the water seller's performance, contracting parties will be more likely to use enforceable contracts when there is an informative signal regarding the reliability of the performance measure. The estimates presented in Table 3 and graphed in Figure 3 provide evidence that soil quality operates as a signal of the correlation between crop output and water delivery.

Table 7 presents more rigorous evidence in support of the final two empirical implications. We report coefficient estimates from linear probability models regarding the effect of an informative signal on the likelihood that a household adopts an output share contract relative to a relational water contract. Panel A treats a rank ordering of signal quality as a continuous variable that has a linear effect on the probability of adopting output share contracts. The quality rank variable equals zero for poor quality soil, one for good quality soil, and two for excellent quality soil. Panel B allows for non-linearity in signal quality by replacing it with indicator variables for each level of quality. This relaxes the assumption that a marginal increase in signal quality has a linear effect on the outcome of interest. Coefficients in column (1) come from a model that excludes village-level controls. Coefficients in column (2) come from a model that includes the Mundlak-Chamberlain device to control for unobserved village-level effects.

Result 3. *There is modest support for Empirical Implication 3, that an increase in the value of the informative signal increases the probability of adopting an output share contract.*

As expected, the rank ordering of signal quality has a positive effect on the probability of adopting output share contracts. Allowing for non-linearity in the variable's effect on contract choice, the coefficient on good and excellent signal quality is positive, but only significant when signal quality is excellent. Focusing on the results in column (1) of panel B, a household with excellent quality soil is eight percent more likely to use output share contracts compared to a household with poor quality soil.

These results, however, are not robust to the inclusion of village-level controls. While coefficients on the signal rank term continues to be positive, it no longer has a statistically significant impact on the contract choice decision. One potential explanation for this is a lack of variation in soil quality within a village. Having controlled for village-level effects, the soil term lacks explanatory power. This intuition is supported by evidence coming from the yield function regressions used to estimate the impact of soil on the mean and variance of yields.[19] That both the coefficient size and significance of good and excellent soil quality are less in the models with village controls compared to the models without village controls indicates that a lack of variation in soil quality at the village-level may be responsible for this lack of robustness in the results.

6.4 Village-Level Punishment

A prominent feature of the theoretical model is the extent to which the severity of punishment influences contract choice. Empirical Implication 4 predicts that output share contracts are more likely in environments where punishment for violation of contracts is severe. Table 4 and Figure 4 present descriptive evidence of this relationship.

Table 7 presents results from basic tests of the predictions regarding the effect of third-party punishment on contract choice. As with signal quality, Panel A treats a rank ordering of punishment as a continuous variable that has a linear effect on the probability of adopting a third-party enforceable contract. The punishment rank variable equals zero for no third-party punishment, one

[19] These regression results are in Table A4 and A5 in the Appendix.

for privately determined punishment, two for economic fine, and three for social ostracism. Panel B allows for non-linearity in the punishment term, thereby relaxing the assumption that a marginal increase in punishment has a linear effect on the outcome of interest. Again, results in column (1) come from a model that excludes village-level controls while in column (2) models include the Mundlak-Chamberlain device to control for unobserved village-level effects.

Result 4. *There is strong and consistent support for Empirical Implication 4, that the number of output share contracts relative to water contracts increases with the availability of harsher punishment for contract breach.*

The positive and significant coefficient on the linear punishment term across both regressions in Panel A implies that as the severity of punishment increases, the probability of adopting an output share contract, which is third-party enforceable increases. This result is robust to the inclusion of village-level controls. In panel B, which allows for non-linear effects in the punishment term, the coefficients on social punishment are positive and significant. Again, these results are robust to the use of village-level controls.

As expected, social ostracism exerts a larger negative effect than other forms of punishment. The marginal effects of a change in village-level governance are large. Focusing on the results from column (2) of panel B, households living in villages that use economic fines to punish contract violation are seven percent more likely to use output share contracts compared to households living in villages that provide no contract enforcement, though this is not statistically different from zero. Households living in villages that use social ostracism are 28 percent more likely to use an enforceable output share contract. Villages with extremely weak enforcement, such as those that allow disputants to determine their own punishment (private punishment), are actually less likely to give rise to output share contracts than self-enforcing water contracts. We conclude that, for surveyed households, the existence of severe third-party punishment has a strong positive effect on the probability of adopting third-party enforceable output share contracts.

In interpreting these results, one may be concerned that the punishment variables are acting as proxies for other factors that may be driving the relationship. Such a bias could exist if villages with better soil were richer and therefore had more developed village institutions. In this case, since soil quality is correlated with village wealth, village characteristics not captured in this term would result in correlation between the punishment variables and the error term. While this is a plausible story, there is no evidence in the data to support it. As a statistical test of this evidence, we can calculate the variance inflation factor (VIF), which measures the degree of collinearity between variables, for each of the models in both panels. The VIFs for the punishment variables and for the soil quality indicators are less than two in every case. The mean VIF for the regressions without village controls are also less than two while the mean VIF for the regressions with village controls are slightly larger than two (2.55 for panel A, 2.52 for panel B). All of these values are not considerably different than one and far from the threshold value of 10, where collinearity becomes a concern (O'Brien, 2007). We conclude that there is no empirical evidence that the punishment variables are acting as proxies for village-level unobservables, such as wealth.

6.5 Robustness Checks

The descriptive and econometric evidence thus far tells a consistent story in regards to the groundwater contract decisions made in rural Bangladesh. The buyer's discount rate does not appear to play an important role in the choice between self-enforcing water contracts, though this is likely due to imperfect data and not a reflection on the model. There is strong and consistent evidence that seller's use their outside option and bargaining power to secure contracts in which they retain *ex post* discretion over any surplus, which is in line with the outside option principle. The evidence regarding the role of an informative signal in increasing the frequency of third-party enforceable output share contracts is modest, with coefficients losing significance when we control for village-level effects. Finally, the evidence regarding the role of governance institutions, particularly the severity of punishment, is strong and consistent across a variety of specifications. Strong institutions that can enforce severe punishment for contract breach allow for parties to use output share contracts while weak or absent institutions require parties to rely on self-enforcing water contracts.

Given that our empirical analysis relies on observable proxies for several of the model's unobservable parameters, it makes sense to wonder how robust our results are to alternative variable definitions. In this section, we briefly discuss the results from a host of robustness checks in which we replace our preferred variable with relevant alternatives from the data. Complete tables of results can be found in the online appendix (see Tables A7 - A13).

First, we check to see if the null result regarding discount rates is maintained when we replace the experimentally elicited discount rate for the period 0-6 months with experimentally elicited rates for alternative time periods. In order to verify that participants' preferences were not time-inconsistent, our experiment elicited intertemporal preferences for 0-6 month, 7-12 month, and 0-12 month periods. In panel A of Table A7 we replace our preferred 0-6 month period with results from the 7-12 month period. In panel B of the same table we use results from the 0-12 month period. In each of these cases, discount rates remain insignificant across all specifications. While the lack of significance is discouraging, the consistency in results is encouraging. So to is the fact that the sign and significance on our measures of outside option and bargaining power are unaffected by alternative measures of the discount rate.

Second, we test the robustness of our second empirical implication to alternative measures of the seller's outside option and the seller's bargaining power. Our preferred definition of a seller's outside option is a binary indicator of whether or not the seller has alternative buyers. As an alternative, the survey asked buyers if they thought the seller was unhappy with them as a buyer. The variable takes a zero if the buyer reports that the seller is unhappy. The logic is that if the seller is unhappy but continues to sell to the buyer, this can be taken as evidence of a lack of a viable outside option for the seller. However, the reverse (a happy seller means a valuable outside option) does not necessarily hold, which is why we prefer our more direct measure in our primary specifications. In Table A8 the coefficients on our alternative proxy for outside option share the same sign with our preferred measure, though they are smaller and frequently insignificant. As an alternative to our measure of seller bargaining power, we use a similar question to our outside option alternative. This question asked buyers if they were unhappy with the seller. The variable takes a one if the buyer reported being unhappy. Again, the logic is that if the buyer is unhappy but continues to contract with the seller, this may be evidence of the seller exerting superior bargaining power. The same caveat applies as before, a happy buyer may not mean the seller lacks bargaining power. In Table A9 we see that our alternative measure of bargaining power has not demonstrable effects on our results. Bargaining power remains positive and significant and there are no changes in the sign and only one change in the significance of the other variables, including interactions. We conclude that the evidence for Empirical Implication 2 is fairly robust to alternative proxies for the seller's outside option and bargaining power.

Third, we examine alternative definitions of what qualifies as a strongly informative signal. While the data lack plausible alternatives to soil quality, we can explore different combinations of the variable, which takes three values: poor, good, and excellent. In Table A10 we group the signal quality proxy in order to compare good/excellent soil to poor soil and excellent soil to good/poor soil. Our main results are robust to these alternative groupings of the variable. In regressions without village-level controls a more informative signal frequently increases the probability of output share contracts being used. And, controlling for village-level unobservables removes any significance.

Fourth, we conduct a similar exercise by making alternative groupings of what qualifies as severe punishment. We compare any punishment (private, economic, or social) to no punishment, economic or social punishment to weak punishment (none or private), and finally we compare social punishment to all other forms (none, private, and economic). Table A11 displays the results. Regardless of how we group the various measures of punishment severity, more severe punishment always has a positive and statistically significant effect on the probability of output share contracts. Additionally, these alternative groupings do not effect the results for signal quality, the coefficients of which continue to be positive and significant without village-level controls and insignificant when we control for village-level unobservables.

The foregoing analysis regarding output share contracts is always in comparison to the two water contracts (fixed price and two-part tariff). Given that payment in fixed price and two-part tariff contracts is contingent on water delivery, and that only two percent of the sample report a third-party present to verify water delivery, we believe the categorization is justified in this setting. However, one might be concerned that since two-part tariffs operate like spot contracts during the season, limiting *ex post* discretion, they require a different level of self-enforcement compared to fixed price contracts. To investigate the sensitivity of the results to the definition of two-part tariffs as relational contracts, we compare output share contracts to only fixed price contracts and then output share to only two-part tariff contracts.

Table A12 present results from this pairwise comparison.[20] Coefficient estimates on the linear effect of punishment are positive and significant in all specifications. Similar results are present for the estimates of the non-linear effects of punishment in panel B of the table. Social punishment is positive and significant in three of the four comparisons of output share contracts to either of the two water contracts. These results suggest that the categorization of two-part tariffs as self-enforcing relational contracts is reasonable, at least in terms of how the contracts respond to changes in enforcement.

7 Conclusion

There is little existing evidence on how different modes of governance influence the decision to adopt different contracts. To address this research gap, this paper uses data on contracts for groundwater irrigation in Bangladesh. We develop a simple model of contract choice in a setting where unverifiable outcomes exist and enforcement varies. We use the model to help explain the empirical regularities in the data, which are robust to more rigorous econometric testing.

Before proceeding, it is important to address the generalizability of the results, given that the empirical application relies on cross-sectional data from a unique contracting environment where institutions vary from village to village. Cross-sectional data does limit the scope of the current investigation. However, since the focus is on institutions, it is not clear that panel or experimental data would generate any additional variation in the primary variable of interest. Considering the difficulty in collecting information on relational contracts, especially in developing countries, related empirical research frequently relies on cross-sectional survey data.[21] Regarding the uniqueness of the setting, key results are not driven by idiosyncrasies in the Bangladeshi irrigation market. Rather, when viewed through the lens of the theoretical model, the empirical evidence appears stable and consistent with rational decisionmaking in what Dixit (2004) calls "the shadow of the

[20] We also verify that our results are not driven by the presence of a few output share contracts that appear in villages without third-party enforcement (see Table A13). Removing these 33 contracts substantially increases the predictive power of our model, meaning that the main results presented in the paper are conservative estimates.

[21] Research includes McMillan and Woodruff (1999), Banerjee and Duflo (2000), Banerji et al. (2012), and Macchiavello and Morjaria (2016).

law." While it is true that few local markets exhibit the degree of variability in enforcement that exists in Bangladesh, one can easily imagine similar results from an analysis of global markets in which institutional enforcement varies from country to country. We leave this for future research.

Two main conclusions emerge from the analysis. First, the types of contracts used to purchase groundwater for irrigation are, to a large extent, determined by the governance institutions that exist to enforce contracts. The theoretical model demonstrates that the severity of punishment levied for contract violation directly impacts contract choice. Descriptive and econometric analysis are indicative of this result. Across a variety of specifications there is strong and consistent evidence that an increase in the severity of punishment increases the probability of parties using output share contracts that rely on a verifiable performance measure of unverifiable agent action.

Second, agents use their outside option and bargaining power to negotiate for a form of contract that leaves them with *ex post* discretion over any surplus. The theoretical model elucidates the importance of strategic uncertainty and rent sharing, particularly in environments lacking third-party enforcement. Empirical analysis reveals that fixed price contracts, in which agents retain *ex post* discretion, are more likely when agents have valuable outside options and/or bargaining power. This result helps explain evidence regarding contract choice in no-enforcement environments.

An important implication of these empirical results is that the contracting environment (i.e., the existence of governance institutions, the severity of punishment, the accuracy of verifiable performance measures, etc) help determine the use of relational or formal contracts while characteristics specific to the contracting parties (i.e., outside options, bargaining power, subjective discount rates, etc) play a role in setting the terms of the contract. Much of the previous work in the empirical contracting literature has not distinguished the effect of individual characteristics from institutional characteristics on contract adoption. The implicit assumption is that all these characteristics have similar effects on both the type of contract (relational or formal) and the form of the contract (output share, fixed price, etc). This lack of distinction has primarily been due to a lack of data distinguishing between formal and relational contracts as well as between varieties of formal and relational contracts. The data provides this distinction and the theoretical and empirical results provide new insight into how the contracting decision is made.

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Table 1: Contract Characteristics

	Contingency of Payment	Timing of Deliverable	Frequency of Delivery	Ease of Verification	Timing of Payment	*Ex Post* Discretion
Fixed Price	Water delivery	Throughout season	Recurring	Difficult	Before delivery	Seller
Two-Part Tariff	Water delivery	Throughout season	Recurring	Difficult	At delivery	Balanced
Output Share	Crop production	End of season	One-time	Easy	After delivery	Buyer

Note: Table provides a summary of the various characteristics of the three forms of contracts used to purchase groundwater for irrigation in Bangladesh. Contingency of payment refers to what deliverable payment will be based upon. Timing of deliverable refers to when, in the life of a contract, the good is delivered. Frequency of delivery refers to how often, during the life of a contract, the good is delivered. Ease of verification refers to the opportunity cost incurred by a third-party in verifying delivery of the good. Timing of payment refers to when, in the life of a contract, payment changes hands. *Ex post* discretion refers to which party has discretion to deviate from the terms of the contract.

Table 2: Contract Type With and Without Enforcement

Panel A: Contract Choice by Discount Rate

	Without Enforcement			With Enforcement		
	Mean	Standard Deviation	Obs.	Mean	Standard Deviation	Obs.
Fixed Price	0.30	0.06	149	0.30	0.06	160
Two-Part Tariff	0.29	0.08	133	0.31	0.06	116
Output Share	0.30	0.06	33	0.30	0.07	116
Obs.			315			392

Panel B: Contract Choice by Outside Option

	Without Enforcement			With Enforcement		
	Outside Option	No Option	Obs.	Outside Option	No Option	Obs.
Fixed Price	96%	4%	149	17%	83%	160
Two-Part Tariff	12%	88%	133	12%	88%	116
Output Share	91%	9%	33	17%	83%	116
Obs.	189	126	315	16	330	392

Panel C: Contract Choice by Bargaining Power

	Without Enforcement			With Enforcement		
	Seller Has Power	Seller Lacks Power	Obs.	Seller Has Power	Seller Lacks Power	Obs.
Fixed Price	54%	46%	149	60%	40%	160
Two-Part Tariff	37%	63%	133	36%	64%	116
Output Share	42%	58%	33	33%	67%	116
Obs.	143	172	315	176	216	392

Note: Panel A displays mean and standard deviations for buyer discount rates divided between whether or not the buyer lives in a village that provides enforcement of contracts. Panel B displays the frequency with which each contract is used based on whether or not the seller has an outside option and village enforcement. Panel C displays the frequency with which each contract is used based on whether or not the seller has bargaining power and village enforcement. Rows sum to 100 while the bottom row presents the total number of observations for each case.

Table 3: Descriptive Statistics of Soil Quality and its Relation To Crop Yield

Panel A: Frequency of Soil Quality

	Poor	Good	Excellent	Obs.
Fixed Price	24%	41%	35%	309
Two-Part Tariff	32%	45%	23%	249
Output Share	16%	40%	44%	149
Obs.	176	297	234	707

Panel B: Yields and Yield Variance by Soil Quality

	ln(yield)	Residuals^2
Poor Quality ($n = 176$)	0.475	0.006
	(0.091)	(0.014)
Good Quality ($n = 297$)	0.486	0.005
	(0.094)	(0.016)
Excellent Quality ($n = 234$)	0.501	0.004
	(0.084)	(0.008)

Note: Panel A presents the rate at which a contract is used on a parcel of a given soil type. Rows sum to 100. The far right column presents the total number of each type of contract observed in the data set while the bottom row presents the total number of observations for each soil type. Panel B presents mean log of yields by soil quality and the mean of the squared residuals from the production function regression in Column (3) of Table A4 in the Appendix. A t-test rejects equality between the residuals for poor soil quality and excellent soil quality at the 90% level.

Table 4: Village Governance Institutions and Punishment Methods

Panel A: Punishment Method By Governance Institution

	None	Private	Economic	Social	Obs.
None	100%	0%	0%	0%	43
Individual	0%	11%	67%	22%	9
Elders	0%	16%	24%	60%	37
Court	0%	0%	100%	0%	7
Obs.	43	7	22	24	96

Panel B: Punishment Method by Contract Type

	None	Private	Economic	Social	Obs.
Fixed Price	48%	9%	26%	17%	309
Two-Part Tariff	53%	9%	22%	16%	249
Output Share	22%	1%	21%	56%	149
Obs.	315	52	165	175	707

Note: Panel A presents the rate at which each village-level governance institution uses a specific punishment method. Rows sum to 100. The far right column presents the frequency of each type of governance institution while the bottom row presents the frequency of punishment method. Panel B presents the rate at which a contract is used within a village employing a given method of punishment. Rows sum to 100. The far right column presents the total number of each type of contract observed in the data set while the bottom row presents the total number of observations of each type of punishment.

Table 5: Descriptive Statistics of Well/Project Characteristics

	Fixed Price	Two-Part Tariff	Output Share
Shallow Tubewell (%)	0.761	0.960	0.846
	(0.427)	(0.197)	(0.363)
Horsepower	11.41	8.422	9.839
	(12.03)	(5.864)	(7.463)
Depth of Water Table (m)	12.67	8.901	11.51
	(6.623)	(3.967)	(5.872)
Time to Irrigate (min/dec)	2.826	3.288	2.640
	(2.281)	(1.721)	(1.735)
Distance from Plot to Well (m)	285.3	170.3	172.6
	(378.6)	(250.6)	(276.8)
Relative or Same Caste (%)	0.375	0.394	0.248
	(0.485)	(0.490)	(0.433)
Seller has Good Reputation (%)	0.369	0.309	0.389
	(0.483)	(0.463)	(0.489)
Obs.	309	249	149

Note: Table presents descriptive statistics for the well owned by the water seller but utilized by the water buyer to irrigate the parcel under contract. The sample is divided by the form of contract used to purchase water from the well.

Table 6: Water Contracts, Discount Rate, Outside Option, and Bargaining Power

	(1)	(2)	(3)	(4)	(5)	(6)
Discount Rate	0.093	−0.001	0.018	−0.076	0.057	0.032
	(0.262)	(0.262)	(0.261)	(0.261)	(0.191)	(0.196)
Seller Outside Option	0.398***	0.485***	0.374***	0.459***	0.365***	0.396***
	(0.057)	(0.066)	(0.061)	(0.068)	(0.062)	(0.072)
Seller Bargaining Power	0.095**	0.156***	0.084**	0.144***	0.087***	0.106**
	(0.041)	(0.052)	(0.041)	(0.052)	(0.032)	(0.042)
Outside Option × Power		−0.171**		−0.168**		−0.056
		(0.075)		(0.072)		(0.068)
Total Effect Outside Option		0.314***		0.291***		0.339***
		(0.069)		(0.073)		(0.070)
Total Effect Bargaining Power		−0.015		−0.024		0.050
		(0.060)		(0.057)		(0.052)
Village Controls	No	No	MC	MC	FE	FE
Observations	558	558	558	558	558	558
Log Likelihood	-302.4	-299.8	-280.4	-277.8	-45.17	-44.61
R^2	0.300	0.306	0.353	0.359	0.248	0.250

Note: Dependent variable is contract choice, where fixed price contract = 1 and two-part tariff contract = 0. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, and if the seller has a good reputation). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table 7: Contract Choice, Punishment, and Informative Signal

	(1)	(2)
Panel A: Linear Effects		
Punishment Rank	0.122***	0.101***
	(0.027)	(0.030)
Signal Rank	0.050**	0.005
	(0.022)	(0.022)
Village Controls	No	MC
Observations	707	707
Log Likelihood	-296.7	-219.0
R^2	0.185	0.346
Panel B: Non-linear Effects		
Private Punishment	−0.038	−0.221**
	(0.037)	(0.093)
Economic Punishment	0.115	0.073
	(0.080)	(0.077)
Social Punishment	0.390***	0.281***
	(0.091)	(0.093)
Good Signal Quality	0.033	−0.011
	(0.036)	(0.035)
Excellent Signal Quality	0.081*	−0.009
	(0.042)	(0.042)
Village Controls	No	MC
Observations	707	707
Log Likelihood	-285.4	-198.3
R^2	0.211	0.383

Note: Dependent variable is contract choice, where output share contract = 1 and water contracts = 0. Panel A explores the linear effects of the variables of interest. Panel B allows for non-linearities by accounting for multiple categorical indicators. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, if the seller has a good reputation, discount rate, seller bargaining power, and seller outside option). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Figure 1: Discount Rates and Water Contracts

Note: The graph draws the kernel densities using individual discount rates. Densities are calculated for households living in villages that provide no contract enforcement and use either fixed price contracts or two-part tariff contracts.

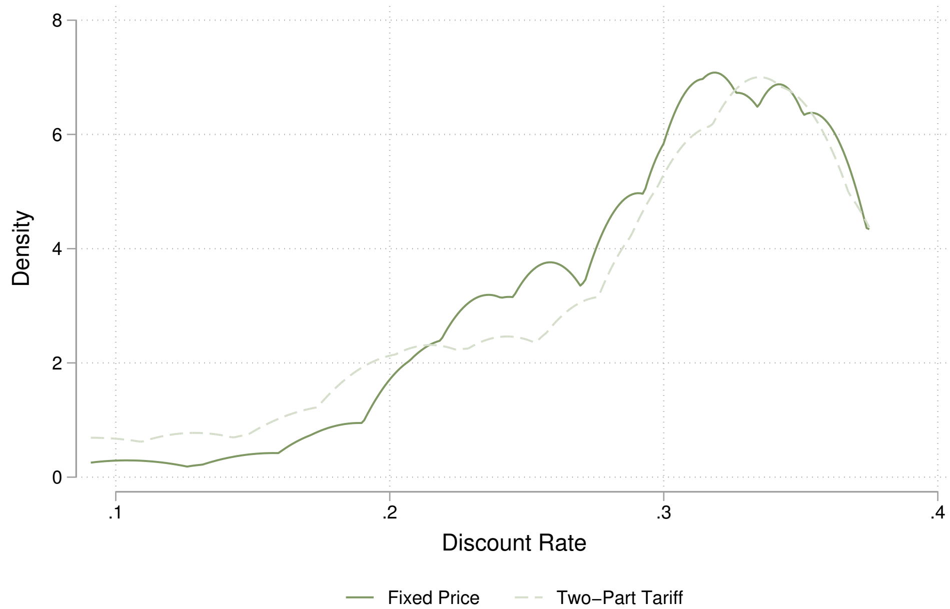


Figure 2: Contract Type and Outside Option

Note: The graph presents contract use by seller outside option and seller bargaining power based on whether or not villages provide contract enforcement, similar to that in Table 2. Panel A tabulates water contract use by outside option in villages without enforcement. Panel B tabulates output share and water contract use by outside option in villages with enforcement. Panel C tabulates water contract use by bargaining power in villages without enforcement. Panel D tabulates output share and water contract use by bargaining power in villages with enforcement.

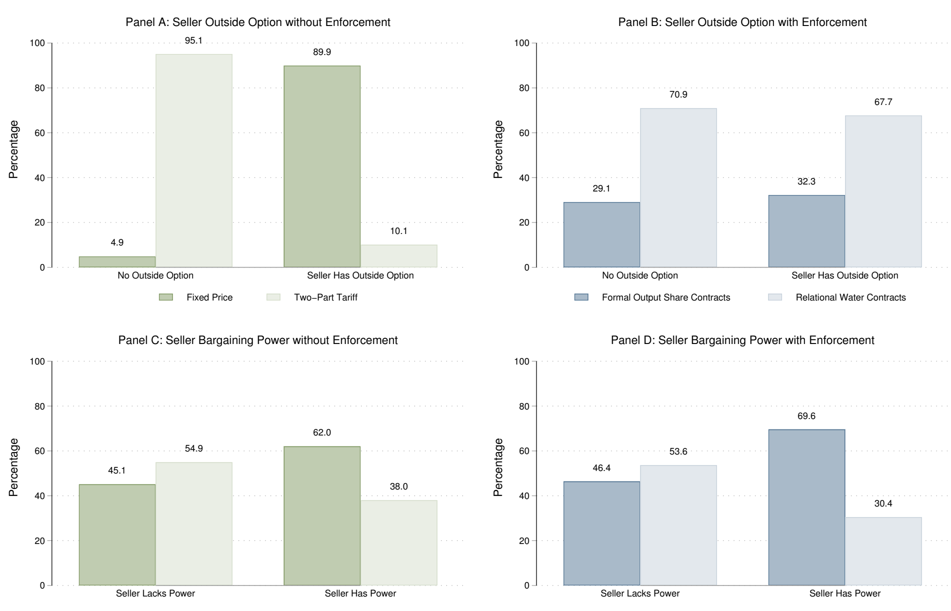


Figure 3: Yield Variance and Soil Quality

Note: The scatter plot is of the squared residuals from the regression presented in column (3) of Table A4 in the Appendix. Since squared residuals are clustered near zero, we use the logarithmic scale on the x-axis to provide visual separation in the graph. Residuals from plots with poor soil quality are denoted with an $\times$, residuals from plots with excellent soil quality are denoted with $\circ$, and residuals from plots with good soil quality are denoted with ▲.

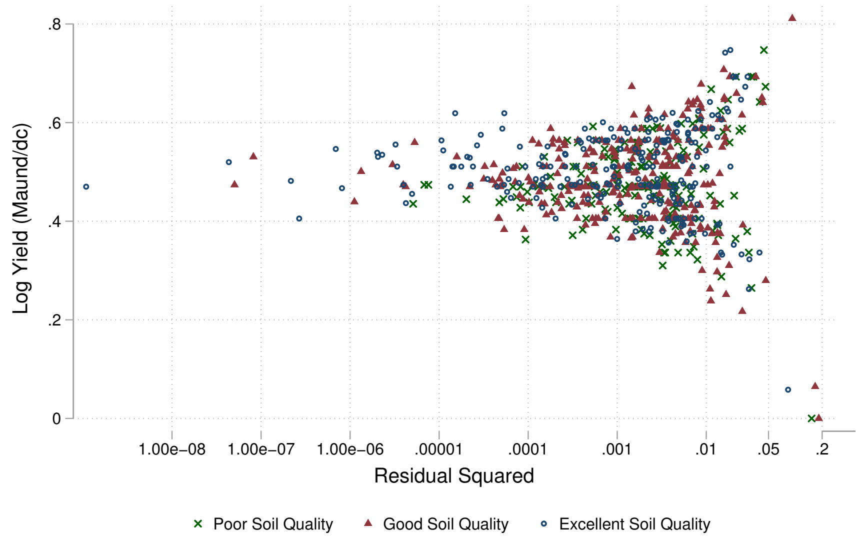
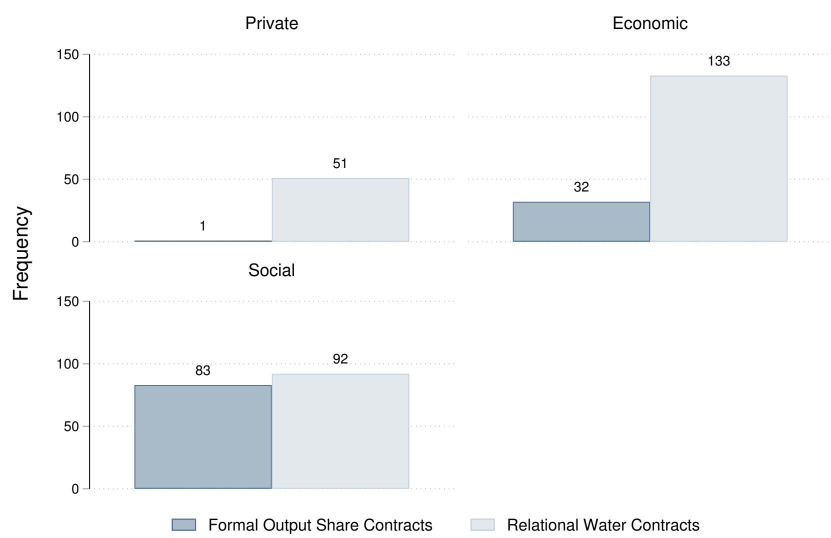


Figure 4: Relational and Formal Contracts and Method of Punishment

Note: The graph presents the frequency of contract use, similar to that in Panel B of Table 4, but with contracts categorized as self-enforcing relational water contracts or third-party enforceable output share contracts. The northwest panel presents the frequency of contracts used in villages that provide enforcement but rely on contracting parties to privately resolve their disputes. The northeast panel presents the frequency of contracts used in villages that impose economic fines. The southwest panel presents the frequency of contracts used in villages that impose social sanctions.



Online-Only Appendix to "The Effects of Governance on Relational and Formal Contracts: Theory and Evidence from Groundwater Irrigation Markets"

This appendix contains additional details and discussion of the market four groundwater irrigation contracts in Bangladesh. It also provides a brief discussion of the experiment used to measure the discount rate and the tests to measure the correlation between soil quality and yield, which is used to justify soil quality as an informative signal in contracting. Finally, it contains the results of the robustness checks discussed in section 6.5.

A The Contracting Environment and Household Characteristics

While we use relationship characteristics as control variables in our econometric analysis, readers may be interested in details regarding the households themselves. Additionally, if there are significant and consistent differences between households in villages with and without enforcement, these differences may represent an omitted variable that impacts both the formation of village-level governance and contract choice.

In Table A1 we report the average prices for each of the contracts in the data. The typical price for irrigation under a fixed price contract is 1,535 Bangladesh Taka, while the typical price for a two-part tariff contract is 1,449. The average output share paid for irrigation was five percent of crop output. Table A2 presents summary statistics for a number of relevant household characteristics by village enforcement. The final column of the table reports the results of a Mann-Whitney test for differences in means between the two populations. Of the ten household characteristics, only one (income per capita) is significantly different across the two populations. For the remaining nine characteristics, there is no significant difference between households living in villages with enforcement and households living in villages without enforcement. The typical household in our study has between four and five members, just under half of which are female. The typical household has about two members of prime labor age (20-49 years old). The typical household head has only five years of formal education. About 20 percent of households have a member who has migrated out of the village for work. Average household earning is between 22,000 and 27,000 Taka per member per year, or around \$350 in 2013 U.S. dollars. Wealth per capita (which sums assets, working capital, and income) is around 80,000 Taka or about $\$1,000$. Land per capita is around 20 decimals or about a fifth of an acre per household member. The vast majority of households (80 percent) own their largest plots, though households may rent in smaller plots. The value of output in Taka per decimal is around 360 Taka, or \$4.5 per fifth of a hectare.

In rural regions, such as our study locations in Bangladesh, it is not uncommon for households to form numerous economic interactions with other households. The development literature has long noted these interlinkages, particularly in terms of tenancy and credit. Landlords frequently lend credit to their tenants, tying the tenant to the land through the use of loans. (Basu, 1990). In Bangladesh, with the prevalence of non-contiguous landholding, it is also possible for household a to sell water to household b for use on one plot while also having household b sell water to household a to irrigate a different plot (Wood and Palmer-Jones, 1991).

While these sorts of economic interlinkages are clearly possible, we find little evidence for their role in our setting. In the survey, households were asked a number of questions regarding their business relationship with their contracting partner. Table A3 provides summary statistics from buyer responses to each of these questions. As is clear from the data, very few water buyers have additional economic ties to the water seller and vice versa.

Finally, as mentioned in the body of the paper, instead of coming from the household data, our punishment variable comes from a village-level survey. Not all households will have experience with contract violations and therefore may have imperfect knowledge of how the village's governance institutions operate. Because of this, we conducted surveys of village governance institutions (when they existed) and use data from these village surveys for the village-level punishment variable. In the village-level survey, the question regarding punishment was as follows:

> "When disputes arise between contracting parties what types of punishments are used to resolve the dispute? These punishments need not actually be used, they could simply be threatened as punishment to help ensure that disputes do not arise. Specifically, when [dispute resolution party] is called upon to resolve a dispute what types of punishment do they threaten to use OR actually use to help resolve the dispute?"

B Measuring the Discount Rate

Numerous issues exist in eliciting individual, subjective interest rates, among which are excessive discounting due to framing, time-inconsistent preferences (including hyperbolic discounting), and a lack of point valuations (Anderson et al., 2006, 2008). These issues can be especially problematic over long time horizons or when the goal is to estimate utility or conduct cost-benefit analysis (Baron, 2000). However, in our setting we do not need to calculate elasticities but simply construct an ordinal ranking of households based on their discount rate. Despite the limited demands on the data, we still attempted to reduce or eliminate the issues of excessive discounting and time-inconsistent preferences through experimental methods. Additionally, we collected data on actual loans given or received to provide a consistency check with the elicited information.

To reduce excessive discounting from framing we followed Coller and Williams (1999) in presenting the choice experiment in both nominal Bangladesh Taka amounts and interest rates. Households were asked to choose between smaller sooner (20,000 Taka) or larger later outcomes (between 21,000 Taka/10 percent and 31,000 Taka/55 percent). This range encompasses the average loan amount received by households in the data, which was 25,000 Taka, but exceeds the average loan amount given by households, which was 18,000 Taka. The mean interest rate elicited from the choice experiment for a 12 month period was 41 percent. We can compare the elicited interest rate to interest rates on actual loans received or given by households for a similar time frame (9-15 months). The mean interest rate on loans was 13 percent from commercial banks, 19 percent from cooperative banks, and 60 percent from money lenders. Mean interest rate on loans given by households was 52 percent. An experimentally elicited mean interest rate of 41 percent is high but within the range of observed interest rates for similar amounts and time periods.

To reduce time-inconsistent responses we follow Read et al. (2005) by asking households to choose smaller sooner or larger later outcomes for various time frames. Specifically, we elicit intertemporal preferences for a 0 to 6 month time frame, a 7 to 12 month time frame, and a 0 to 12 month time frame. By comparing interest rates across time frames we can determine if households exhibit hyperbolic discounting ($i_{0-6} > i_{7-12}$). We find little evidence of hyperbolic discount, with a mean interest rate of .440 for the 0-6 month period and a mean interest rate of .442 for the 7-12 month period. Looking within households, only 20 percent demonstrated hyperbolic discounting while the remaining 80 percent demonstrated time consistent preferences.

While we have taken care to address the issues of framing and time-inconsistencies, we have not generated point valuations but rather only elicited interval responses. Given the criticisms of point valuations by Harrison (1992) we adhered to the more parsimonious experimental approach of interval elicitation. The larger later choices ranged from an interest rate of 10 percent to 55 percent at 5 percent intervals. This gives us eleven intervals by which to order households. We convert experimentally elicited interest rates to the subjective discount rates using the equation $r = 1/(1 + i)$ where r is the discount rate and i is the interest rate. In constructing the range of interest rates to be between 10 and 55 percent, we may have in fact cut off the top end of the distribution, causing bunching of outcomes, and limiting our ability to estimate the impact of the discount rate on contract choice.

C Soil Quality as an Informative Signal

Empirical measures of the noisiness of the relationship between water delivery (y) and observable crop output (q) are difficult to come by. Such a measure should relate to the marginal impact of water on the probability of a successful crop yield, and thus should be related to $f'(y)$. While we do not have an exact measure of $f'(y)$, we do have data on soil quality. The logic is that if soil quality is poor, crop output is likely to be poor regardless of water. However, when soil quality is high, then crop output is more sensitive to water and serves as a more informative signal of whether the seller delivered water. Thus, soil quality can serve as a proxy for the degree to which crop yield is responsive to water.

To test this logic, we want to verify two empirical relationships. First, does better soil result in higher crop output, meaning does better soil increase the probability of successful crop output? Second, does better soil reduce the variance in crop output, meaning does better soil reduce the noise in the relationship between water delivery and crop output? If there is empirical evidence that soil quality is effective in both of these roles, we can consider soil quality as an informative signal regarding the agent's performance. Recall that the informativeness principle states that any additional information, however imperfect, can be used to improve outcomes in formal contracts (Holmstrom, 1979). When soil quality is extremely poor, crop yield provides no information regarding the delivering of water. As soil quality increases, the noise in the contracting relationship is reduced. Better soil reveals (on the margin) information about agent action in delivering water.

The data set contains information on the soil quality of irrigated parcels in the form of the color/consistency of the soil. Quality ranges from high quality (black and rich) to poor quality (sandy and alkaline). We aggregate soil quality information into a simple ranking of soil as either poor, good, or excellent. By construction, soil quality is approximately normally distributed (see Panel A in Table A6).

To verify that the soil quality rankings are accurate, we first run a regression of crop output on inputs using a parsimonious yield function, with indicator variables for soil type. We estimate the model with no geographic indicators, with division-level fixed effects, and with village-level fixed effects to account for potential unobserved regional differences in weather and production technologies. Results from all three regressions are presented in Table A4. An important result of the yield regressions is that contract type is not related to yield. The coefficients on excellent quality soil are positive and significantly improve output compared to poor quality soil in all three regressions. However, the coefficients on good quality soil are only significant in the regressions that exclude village fixed effects. As is seen in our analysis of contract choice, controlling for village-level effects has a strong influence on the size and significance of the soil variables. We hypothesize that this is due to a lack of variation in soil quality at the village-level. By including village-level controls in the yield regression or by including them in the contract choice regression we no longer have enough variation in soil quality at the village-level to pick up a statistically significant effect in soil quality.

An additional indication that soil quality acts as an informative signal would be if yields are more responsive to water when soil quality is good. To test this we interact the soil quality indicators with the amount of irrigated water applied to the plot. Results from three regressions are presented in Table A5. These results are not as consistent as the previous results. However, we do find that the interaction between quantity of water and excellent soil is positive and significant. This indicates that yields are more responsive to water when soil quality is excellent than when soil quality is poor.

While the regression results generally confirm that better quality soil increases yield, what we are really interested in is if better quality soil reduces the variance or noise in yield. To accomplish this, we square the residuals from the yield regression with village-level fixed effects and compare the mean of the squared residuals across soil type (see Panel B in Table A6). Not only does better soil quality increase yield but better soil quality is associated with a reduction in the variance of yield, exactly what we want from an informative signal. We conduct a Mann-Whitney test for equality of means across the three groups, allowing for heterogeneity in the group covariance matrices. We reject the null of equality of means at the 90 percent confidence level.

Table A1: Price of Irrigation

	Price
Fixed Price	1,535
	(2,614)
Output Share	0.053
	(0.107)
First Two-Part Tariff Payment	437.0
	(843.9)
Second Two-Part Tariff Payment	1,012
	(1,857)
Total Two-Part Tariff Price	1,449
	(2,562)

Note: Table presents mean of buyer reported prices paid for each type of contract (standard deviations in parenthesis). Prices in Taka.

Table A2: Household Characteristics by Village Enforcement

	Without Enforcement	With Enforcement	MW-test
Num. of Household Members	4.687	4.757	
	(1.498)	(1.449)	
Share of Female Members	0.458	0.467	
	(0.158)	(0.158)	
Num. of Prime Age Laborers (20-49)	2.268	2.169	
	(1.081)	(0.896)	
Education of Household Head (years)	4.578	4.909	
	(4.044)	(4.307)	
Household has Migrant (=1)	0.225	0.220	
	(0.575)	(0.565)	
Income per Capita (Taka)	22,067	27,019	**
	(20,840)	(35,251)	
Wealth per Capita (Taka)	79,567	82,078	
	(91,688)	(80,819)	
Land per Capita (dc)	20.37	20.27	
	(13.92)	(14.79)	
Owns Largest Parcel (=1)	0.834	0.794	
	(0.372)	(0.404)	
Area of Largest Parcel (dc)	47.66	49.40	
	(26.06)	(28.54)	
Value of Output (Taka/dc)	362.4	360.5	
	(93.40)	(98.65)	
Observations	315	392	

Note: Table present means of household characteristics for water buyers analyzed in the paper (standard deviations in parenthesis). Summary statistics are presented for households in villages without and with third-party contract enforcement. The final column presents the results of the Mann-Whitney test for differences in mean between the two populations, with significance levels (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A3: Interlinked Contracts

	% Yes	% No
Are Wayer Buyer and Water Seller Partners in Another Business?	4.67	95.33
Does Water Buyer Provide Irrigation to Any Plot Owned by Water Seller?	1.42	98.58
Does Water Buyer Rent Any Plots from Water Seller?	3.83	96.17
Does Water Seller Rent Any Plots from Water Buyer?	1.84	98.16
Has the Water Seller Made a Loan to the Water Buyer?	3.97	96.03
Has the Water Buyer Made a Loan to the Water Seller?	3.83	96.17

Note: Table present frequency with which a household responded "yes" or "no" to the stated survey questions.

Table A4: Estimation Results of Production Function

ln*(yield)*	(1)	(2)	(3)
Good Soil Quality	0.014*	0.016**	0.015
	(0.008)	(0.008)	(0.010)
Excellent Soil Quality	0.027***	0.025***	0.016*
	(0.009)	(0.009)	(0.010)
Contract Type	0.014	0.015	−0.007
	(0.009)	(0.012)	(0.018)
ln(Labor)	−0.009**	−0.006	−0.004
	(0.004)	(0.004)	(0.003)
ln(Fertilizer)	0.003	0.004	0.005
	(0.004)	(0.004)	(0.004)
ln(Pesticide)	−0.002	−0.001	−0.002
	(0.002)	(0.002)	(0.002)
ln(Irrigation)	0.031***	0.033***	0.028*
	(0.012)	(0.012)	(0.016)
ln(Other Material)	0.010**	0.012**	0.014**
	(0.005)	(0.005)	(0.006)
Tenure	−0.007	−0.008	−0.008
	(0.008)	(0.009)	(0.009)
ln(Wealth Per Capita)	0.012**	0.014**	0.013**
	(0.006)	(0.006)	(0.006)
ln(Land Per Capita)	0.007	0.006	0.003
	(0.005)	(0.004)	(0.006)
Subjective Interest Rate	0.010	0.015	0.016
	(0.026)	(0.026)	(0.027)
Shallow Tubewell	−0.028**	−0.023*	−0.018
	(0.013)	(0.013)	(0.016)
ln(Horsepower)	0.002	0.002	−0.001
	(0.007)	(0.007)	(0.007)
ln(Water Table Depth)	−0.007	−0.004	0.005
	(0.010)	(0.009)	(0.011)
Fixed Effects	None	Division	Village
Observations	707	707	707
R^2	0.090	0.116	0.331

Note: The table presents correlation between production inputs and log of rice yield. Fixed effect indicator variables for four of the five divisions are included in column (2) while column (3) reports results using indicators for 95 of the 96 villages. Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A5: Estimation Results of Production Function with Interactions

ln*(yield)*	(1)	(2)	(3)
Good	−0.051	−0.048	−0.009
	(0.083)	(0.081)	(0.083)
Excellent	−0.142	−0.139	−0.178
	(0.109)	(0.109)	(0.108)
ln(Irrigation)	0.014	0.016	0.014
	(0.020)	(0.020)	(0.024)
Good × ln(Irrigation)	0.015	0.015	0.006
	(0.019)	(0.019)	(0.020)
Excellent × ln(Irrigation)	0.039	0.038	0.046*
	(0.025)	(0.025)	(0.025)
Contract Type	0.015*	0.015	−0.009
	(0.009)	(0.012)	(0.018)
ln(Labor)	−0.009**	−0.005	−0.004
	(0.004)	(0.004)	(0.003)
ln(Fertilizer)	0.003	0.004	0.005
	(0.004)	(0.004)	(0.004)
ln(Pesticide)	−0.002	−0.001	−0.002
	(0.002)	(0.002)	(0.002)
ln(Other Material)	0.010*	0.012**	0.014**
	(0.005)	(0.005)	(0.006)
Tenure	−0.007	−0.008	−0.006
	(0.008)	(0.009)	(0.009)
ln(Wealth Per Capita)	0.012**	0.014**	0.012**
	(0.006)	(0.005)	(0.006)
ln(Land Per Capita)	0.006	0.005	0.003
	(0.005)	(0.004)	(0.006)
Subjective Interest Rate	0.005	0.010	0.008
	(0.025)	(0.024)	(0.028)
Shallow Tubewell	−0.029**	−0.024*	−0.020
	(0.013)	(0.013)	(0.016)
ln(Horsepower)	0.002	0.003	−0.000
	(0.007)	(0.007)	(0.007)
ln(Water Table Depth)	−0.007	−0.004	0.006
	(0.010)	(0.010)	(0.011)
Fixed Effects	None	Division	Village
Observations	707	707	707
R^2	0.097	0.123	0.342

Note: The table presents correlation between production inputs and log of rice yield. Fixed effect indicator variables for four of the five divisions are included in column (2) while column (3) reports results using indicators for 95 of the 96 villages. Cluster corrected robust standard errors are reported in parentheses ($^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$).

Table A6: Descriptive Statistics of Soil Quality and its Relation To Crop Yield

Panel A: Frequency of Soil Quality

	Poor	Good	Excellent	Obs.
Fixed Price	42%	42%	47%	309
Two-Part Tariff	45%	38%	25%	249
Output Share	14%	20%	28%	149
Obs.	176	297	234	707

Panel B: Yields and Yield Variance by Soil Quality

	ln(yield)	Residuals^2
Poor Quality ($n = 176$)	0.475	0.006
	(0.091)	(0.014)
Good Quality ($n = 297$)	0.486	0.005
	(0.094)	(0.016)
Excellent Quality ($n = 234$)	0.501	0.004
	(0.084)	(0.008)

Note: Panel A presents frequency of soil type by observations of each type of contract. Panel B presents mean log of yields by soil quality and the mean of the squared residuals from the production function regression in Column (3) of Table A4. A t-test rejects equality between the residuals for poor soil quality and excellent soil quality at the 90% level.

Table A7: Water Contracts and Alternative Measure of Discount Rates

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Discount Rate for 7-12 months						
Discount Rate (7-12 months)	-0.067	-0.200	-0.042	-0.173	-0.049	-0.090
	(0.312)	(0.310)	(0.298)	(0.297)	(0.207)	(0.213)
Seller Outside Option	0.398^{***}	0.489^{***}	0.374^{***}	0.461^{***}	0.365^{***}	0.398^{***}
	(0.058)	(0.066)	(0.062)	(0.068)	(0.063)	(0.072)
Seller Bargaining Power	0.097^{**}	0.161^{***}	0.084^{**}	0.146^{***}	0.089^{***}	0.110^{***}
	(0.041)	(0.052)	(0.041)	(0.052)	(0.032)	(0.041)
Outside Option × Power		-0.180^{**}		-0.173^{**}		-0.062
		(0.075)		(0.072)		(0.068)
Village Controls	No	No	MC	MC	FE	FE
Observations	558	558	558	558	558	558
Log Likelihood	-302.4	-299.8	-280.4	-277.8	-45.17	-44.61
R^2	0.300	0.306	0.353	0.359	0.248	0.250
Panel B: Discount Rate for 0-12 months						
Discount Rate (0-12 months)	-0.021	-0.088	-0.039	-0.107	-0.118	-0.142
	(0.243)	(0.248)	(0.231)	(0.235)	(0.169)	(0.173)
Seller Outside Option	0.398^{***}	0.486^{***}	0.374^{***}	0.458^{***}	0.364^{***}	0.398^{***}
	(0.058)	(0.067)	(0.062)	(0.068)	(0.063)	(0.072)
Seller Bargaining Power	0.096^{**}	0.158^{***}	0.084^{**}	0.144^{***}	0.090^{***}	0.112^{***}
	(0.042)	(0.052)	(0.041)	(0.052)	(0.031)	(0.041)
Outside Option × Power		-0.174^{**}		-0.168^{**}		-0.063
		(0.075)		(0.073)		(0.067)
Village Controls	No	No	MC	MC	FE	FE
Observations	558	558	558	558	558	558
Log Likelihood	-302.44	-299.74	-280.42	-277.71	-44.98	-44.29
R^2	0.299	0.306	0.353	0.359	0.249	0.251

Note: Dependent variable is contract choice, where fixed price contract = 1 and two-part tariff contract = 0. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, and if the seller has a good reputation). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A8: Water Contracts and Alternative Measure of Outside Option

	(1)	(2)	(3)	(4)	(5)	(6)
Discount Rate	0.116	0.164	0.016	0.076	0.078	0.102
	(0.288)	(0.287)	(0.291)	(0.290)	(0.213)	(0.219)
Seller Outside Option (Seller happy)	0.105	0.261**	0.074	0.265***	0.020	0.100
	(0.066)	(0.102)	(0.060)	(0.095)	(0.045)	(0.072)
Seller Bargaining Power	0.129***	0.155***	0.116**	0.148***	0.137***	0.151***
	(0.045)	(0.049)	(0.044)	(0.049)	(0.035)	(0.039)
Outside Option (Seller happy) × Power		−0.268*		−0.331**		−0.140
		(0.136)		(0.132)		(0.093)
Total Effect Outside Option (Seller happy)		−0.008		−0.066		−0.040
		(0.087)		(0.081)		(0.058)
Total Effect Bargaining Power		−0.113		−0.182		0.011
		(0.121)		(0.114)		(0.077)
Village Controls	No	No	MC	MC	FE	FE
Observations	557	557	557	557	557	557
Log Likelihood	-350.4	-348.2	-323.4	-319.8	-99.92	-98.71
R^2	0.166	0.172	0.243	0.253	0.087	0.090

Note: Dependent variable is contract choice, where fixed price contract = 1 and two-part tariff contract = 0. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, and if the seller has a good reputation). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A9: Water Contracts and Alternative Measure of Bargaining Power

	(1)	(2)	(3)	(4)	(5)	(6)
Discount Rate	0.150	0.128	0.065	0.043	0.130	0.110
	(0.257)	(0.256)	(0.257)	(0.257)	(0.185)	(0.184)
Seller Outside Option	0.407***	0.428***	0.379***	0.402***	0.384***	0.405***
	(0.056)	(0.060)	(0.059)	(0.063)	(0.063)	(0.063)
Seller Bargaining Power (Buyer unhappy)	0.126**	0.185**	0.142**	0.203**	0.051	0.112*
	(0.057)	(0.079)	(0.063)	(0.082)	(0.042)	(0.058)
Outside Option $\times$ Power (Buyer unhappy)		−0.149		−0.155*		−0.149**
		(0.096)		(0.088)		(0.072)
Total Effect Outside Option		0.279***		0.247***		0.256***
		(0.088)		(0.086)		(0.087)
Total Effect Bargaining Power (Buyer unhappy)		0.036		0.048		−0.037
		(0.066)		(0.066)		(0.049)
Village Controls	No	No	MC	MC	FE	FE
Observations	558	558	558	558	558	558
Log Likelihood	-303.1	-302.1	-279.7	-278.6	-50.08	-47.97
R^2	0.298	0.300	0.354	0.357	0.235	0.241

Note: Dependent variable is contract choice, where fixed price contract = 1 and two-part tariff contract = 0. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, and if the seller has a good reputation). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A10: Contract Choice and Alternative Grouping of Signal

	(1)	(2)	(3)	(4)
	Panel A: Linear Effects			
Punishment Rank	0.123***	0.102***	0.122***	0.101***
	(0.027)	(0.029)	(0.027)	(0.030)
Good/Excellent Signal Quality	0.071**	0.005		
	(0.033)	(0.035)		
Excellent Signal Quality			0.066*	0.008
			(0.039)	(0.036)
Village Controls	No	MC	No	MC
Observations	707	707	707	707
Log Likelihood	-297.8	-219.0	-297.7	-219.0
R^2	0.183	0.346	0.183	0.346
	Panel B: Non-linear Effects			
Private Punishment	−0.036	−0.221**	−0.040	−0.221**
	(0.035)	(0.093)	(0.037)	(0.094)
Economic Punishment	0.118	0.073	0.113	0.073
	(0.079)	(0.076)	(0.079)	(0.077)
Social Punishment	0.396***	0.281***	0.392***	0.281***
	(0.090)	(0.092)	(0.091)	(0.092)
Good/Excellent Soil Quality	0.053	−0.010		
	(0.033)	(0.034)		
Excellent Soil Quality			0.059	−0.001
			(0.037)	(0.033)
Village Controls	No	MC	No	MC
Observations	707	707	707	707
Log Likelihood	-286.5	-198.4	-285.9	-198.4
R^2	0.208	0.383	0.210	0.383

Note: Dependent variable is contract choice, where output share contract = 1 and water contracts = 0. Panel A explores the linear effects of the variables of interest. Panel B allows for non-linearities by accounting for multiple categorical indicators. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, if the seller has a good reputation, discount rate, seller bargaining power, and seller outside option). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A11: Contract Choice and Alternative Grouping of Punishment

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Linear Effects						
Private/Economic/Social Punishment	0.219***	0.141**				
	(0.060)	(0.068)				
Economic/Social Punishment			0.263***	0.238***		
			(0.065)	(0.071)		
Social Punishment					0.353***	0.297***
					(0.093)	(0.089)
Signal Rank	0.062**	0.018	0.057**	0.008	0.041*	−0.001
	(0.024)	(0.023)	(0.023)	(0.023)	(0.021)	(0.021)
Village Controls	No	MC	No	MC	No	MC
Observations	707	707	707	707	707	707
Log Likelihood	-321.6	-243.5	-308.2	-221.5	-291.4	-211.7
R^2	0.126	0.299	0.158	0.341	0.197	0.359
Panel B: Non-linear Effects						
Private/Economic/Social Punishment	0.219***	0.140**				
	(0.061)	(0.068)				
Economic/Social Punishment			0.263***	0.238***		
			(0.065)	(0.071)		
Social Punishment					0.353***	0.297***
					(0.093)	(0.089)
Good Signal Quality	0.064	0.010	0.058	0.005	0.028	−0.009
	(0.040)	(0.037)	(0.037)	(0.035)	(0.036)	(0.036)
Excellent Signal Quality	0.125***	0.034	0.113**	0.016	0.081*	−0.003
	(0.047)	(0.046)	(0.045)	(0.045)	(0.042)	(0.042)
Village Controls	No	MC	No	MC	No	MC
Observations	707	707	707	707	707	707
Log Likelihood	-321.9	-243.5	-308.2	-221.5	-291.3	-211.6
R^2	0.126	0.299	0.158	0.341	0.197	0.360

Note: Dependent variable is contract choice, where output share contract = 1 and water contracts = 0. Panel A explores the linear effects of the variables of interest. Panel B allows for non-linearities by accounting for multiple categorical indicators. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, if the seller has a good reputation, discount rate, seller bargaining power, and seller outside option). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A12: Pairwise Comparison Between Contracts

	Output Share to Fixed Price		*Output Share to Two-Part Tariff*	
	(1)	(2)	(3)	(4)
		Panel A: Linear Effects		
Punishment Rank	0.151***	0.129***	0.159***	0.125***
	(0.039)	(0.047)	(0.033)	(0.033)
Signal Rank	0.056*	0.002	0.042	−0.002
	(0.033)	(0.035)	(0.029)	(0.023)
Village Controls	No	MC	No	MC
Observations	458	458	398	398
Log Likelihood	-244.3	-191.7	-182.4	-111.0
R^2	0.225	0.384	0.375	0.563
		Panel B: Non-linear Effects		
Private Punishment	−0.160	−0.479***	−0.062	−0.137
	(0.101)	(0.167)	(0.067)	(0.101)
Economic Punishment	0.099	−0.004	0.178	0.082
	(0.122)	(0.116)	(0.124)	(0.104)
Social Punishment	0.388***	0.207	0.499***	0.378***
	(0.122)	(0.131)	(0.106)	(0.102)
Good Signal Quality	0.039	−0.008	0.033	−0.008
	(0.061)	(0.057)	(0.046)	(0.041)
Excellent Signal Quality	0.087	−0.013	0.067	−0.025
	(0.066)	(0.064)	(0.057)	(0.043)
Village Controls	No	MC	No	MC
Observations	458	458	398	398
Log Likelihood	-235.9	-171.0	-174.8	-97.16
R^2	0.253	0.437	0.398	0.593

Note: Dependent variable is contract choice, where output share contract = 1 and water contracts = 0. Panel A explores the linear effects of the variables of interest. Panel B allows for non-linearities by accounting for multiple categorical indicators. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, if the seller has a good reputation, discount rate, seller bargaining power, and seller outside option). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table A13: Punishment and Informative Signal without Relational Output Share Contracts

	(1)	(2)
Panel A: Linear Effects		
Punishment Rank	0.146***	0.123***
	(0.026)	(0.026)
Signal Rank	0.042**	−0.001
	(0.020)	(0.020)
Village Controls	No	MC
Observations	674	674
Log Likelihood	-181.0	-102.8
R^2	0.295	0.443

	(1)	(2)
Panel B: Non-linear Effects		
Private Punishment	0.017	−0.155*
	(0.027)	(0.083)
Economic Punishment	0.196***	0.145**
	(0.074)	(0.070)
Social Punishment	0.458***	0.344***
	(0.089)	(0.085)
Good Signal Quality	0.060*	0.010
	(0.033)	(0.030)
Excellent Signal Quality	0.073*	−0.013
	(0.039)	(0.037)
Village Controls	No	MC
Observations	674	674
Log Likelihood	-172.3	-82.96
R^2	0.315	0.474

Note: Dependent variable is contract choice, where output share contract = 1 and water contracts = 0. Panel A explores the linear effects of the variables of interest. Panel B allows for non-linearities by accounting for multiple categorical indicators. Each regression includes a set of well/project characteristics (if well is a shallow tubewell, pump horsepower, log of water table depth, log of time to irrigate, log of distance from well to plot, if buyer and seller are related, if the seller has a good reputation, discount rate, seller bargaining power, and seller outside option). Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).