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

Jeffrey D. Michler* Steven Y. Wu

April 2015

Abstract

This paper examines evidence on the role different types of governance plays in the adoption of relational or formal contracts. We conduct our empirical analysis using a unique data set on contracts for groundwater irrigation in Bangladesh. In this market, households seeking to secure groundwater irrigation can either exploit high-quality inside information to design contracts or rely on low-quality but third-party verifiable information. A distinguishing feature of this market is the existence of a variety of different village-level institutions for the enforcement of contracts. This allows us to examine both the determinants of contract choice under a specific governance regime and how differences in governance affect contract choice. We adapt existing models of relational contracts to integrate stylized observations from the field and derive empirical tests based on comparative static predictions. We find that households adopt formal contracts when the quality of third-party verifiable information is good and when the punishment for contract violation is severe. We also find that in villages which provide no third-party enforcement the issue of who retains *ex post* discretion is particularly important. Contracting parties attempt to balance counter party risk by using bargaining power to force adoption of contracts in which they retain *ex post* discretion.

JEL Classification: D82; L14; O12; Q15; Z13
Keywords: Relational Contracts; Contract Enforcement; Verifiability Problem; Groundwater Irrigation

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*Department of Agricultural Economics, Purdue University, 403 West State Street, West Lafayette, IN, 47907. Email: jmichler@purdue.edu. The authors owe a particular debt to Humnath Bhandari at International Rice Research Institute (IRRI), Dhaka, and Saidur Rahman at Bangladesh Agricultural University, Mymensingh, for assistance and support in conducting the fieldwork associated with this study. This work has benefited from helpful comments by Stephen Martin, Michael Delgado, Juan Sesmero, as well as seminar participants at the Midwest Development Conference in Minneapolis, MN the Agricultural and Applied Economics Association Annual Meeting in Washington, D.C., and the International Rice Congress in Bangkok, Thailand. Financial support for this project was provided by the Purdue Center for Global Food Security and the Social Sciences Division at IRRI, Los Banos, Philippines.

1 Introduction

When contracting on observables is prohibitively expensive (Baker et al., 1994) or when legal institutions are weak (Dixit, 2004), relational contracts may generate larger surplus than the best available formal contracts. In these cases, contracting parties can choose to exploit high-quality inside information to design optimal contracts. Or, if imperfect signals of agent action can be observed and verified by a third-party with minimal cost, contracting parties can design formal contracts based on this low-quality information (MacLeod, 2007). Even in situations where formal contracting is more costly than relational contracting, formal contracts can be used to create a threat-point payoff that ensures self-enforcement constraints are satisfied in a relational contract. Thus, relational contracts are primarily concerned with a verifiability problem that leads to enforcement issues.

This article focuses on the role of relational and formal contracts in resolving the verifiability problem in the market for groundwater irrigation in Bangladesh. We adapt relational contracting models to stylized observations from the field and derive useful comparative static predictions. Our key theoretical predictions are that relational contracts will be preferred to formal contracts when the accuracy of the verifiable performance signal is poor and when institutional enforcement is weak. Using a unique data set on groundwater contracts in Bangladesh, we examine the decision to adopt relational or formal contracts within and across different structures of governance. We find empirical evidence of a strong negative correlation between the severity of punishment and the adoption of relational contracts. We find mixed evidence that relational contracts are preferred when verifiable information is inaccurate.

The effect of governance on groundwater contracts is an especially pressing issue in Bangladesh as the country is rapidly expanding its irrigated area and looking to improve its legal institutions (Hossain, 2009). Three key features distinguish the market for groundwater irrigation in Bangladesh from groundwater markets in more developed countries. The first is a lack of credible institutional legal authority beyond the village. The second is the difficulty for an third-party to verify the delivery of sufficient water for crop production. The third is a variation across villages in the governance structure for enforcing contracts. These institutional features mean that relational contract theory is well suited to provide clarity regarding the real world environment 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. Within some villages, extralegal institutions exist that may be relied upon to provide some degree of contract enforcement. Such extralegal institutions include councils of village elders, a village headman, and religious leaders. While these institutions may be called on to adjudicate disputes, their authority is informal and their decisions are not legally binding. Even if the rulings of village institutions were legally binding, 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 throughout the season (usually spanning 120 days). Thus, unlike many products governed by relational contracts (Hueth et al., 1999; Goodhue, 2000; Leegomonchai and Vukina, 2005), there is no single delivery date for irrigation. In theory, a third-party could observe each delivery of water throughout the season to verify that the contracted amount of water was delivered. Yet, this is a costly proposition, meaning contracting parties may be able to use relational contracts to obtain welfare improving outcomes.

But not every household has the opportunity to choose between relational and village-level enforceable contracts. While enforcement of contracts by village institutions is prevalent, not all villages provide such enforcement. In fact, about forty-five percent of villages in our study provide no enforcement mechanism at all. This creates a contracting environment where some households can use relational contracts with enforceable contracts as a fall back option while other households lack this opportunity. We exploit variations in village-level governance to examine not just the determinants of contract choice under a specific governance regime, as other studies do, but to investigate how differences in governance affect contract choice.

Given this institutional setting, we use the following taxonomy throughout the paper. *Legally-binding contracts* are written contracts based on third-party verifiable information and are legally enforceable by the court system. While these contracts are used in Bangladesh, particularly in the garment industry (Ahmed et al., 2014), they are not used in the market for groundwater irrigation because of low literacy rates and the high cost to rural households in attempting to enforce contracts in distant courts. *Formal contracts* are verbal contracts based on third-party verifiable information. These contracts are enforceable at the village-level by an agreed upon arbitration party, usually a group of village elders. The enforceability of formal contracts may allow such contracts to serve as a default obligation for relational contracts. A *relational contract* is a verbal contract based on observable but not third-party verifiable information. These contracts are not enforceable by an arbitration party, meaning enforcement relies on the value to each party of repeated trading. The existence of observable but not verifiable information means that the primary problem in contracting for groundwater irrigation in Bangladesh is verifiability and not asymmetric information or moral hazard.

We modify relational contracting models developed by Baker et al. (1994, 2002) and Dixit (2004) to integrate stylized observations from the field. This allows us to focus on the key features of groundwater markets in Bangladesh and derive useful comparative statics predictions for conducting empirical analyses. We evaluate the empirical validity of these theoretical predictions using a new dataset from Bangladesh specifically collected to investigate contracting and efficiency in the market for groundwater irrigation. The data consist of 960 households randomly selected from 96 villages chosen to provide representative coverage of irrigated rice production in Bangladesh. Along with information on farm production and household characteristics, the survey includes information on current contracting relationships, the history of those relationships, and previous contracting practices. Supplementing the household level survey is a village-level survey which was designed to gather information on village-level contract enforcement and sanctions for contract violation.

We apply the theory of relational contracts in which contracting parties have high-quality but unverifiable information to the market for groundwater irrigation in Bangladesh. In doing so, we build on and contribute to three separate streams of literature. The first is the empirical literature on relational contracting and the interplay between relational and formal contracts. The second is the literature on contract choice and the role of risk preferences, bargaining power and agency incentives in the form of *ex post* discretion. The third is the literature on the structure and function of groundwater irrigation markets in countries with weak legal institutions.

A key insight from the relational contracting literature is that formal contracts can operate as complements or substitutes to relational contracts depending on the institutional environment (MacLeod, 2007). Most studies that examine this empirical question examine contracts within a uniform enforcement environment. Studies that find relational and formal contracts to be substitutes include Corts and Singh (2004), Cohen et al. (2015), and Antras and Foley (2015). Corts and Singh (2004) examine the market for offshore drilling where formal contracts may be costly but enforcement is a non-issue. Cohen et al. (2015) study how the discount rate of NBA coaches changes their behavior, given an institutional environment that provides strong, consistent enforcement on objective measures. Antras and Foley (2015) look at contracts across a variety of institutional enforcement mechanisms in the context of a single seller in the processed poultry market. They find that the seller chooses contract types to manage counter party risk, depending on the reliability of local legal institutions. The consistent result in these studies is that relational and formal contracts are substitutes. A decrease in the cost of formal contracting reduces the likelihood of relational contracts. In contrast, several studies find that relational and formal contracts might not act as substitutes and may even be complements. Banerjee and Duflo (2000) study Indian software companies within a consistently weak institutional environment. Yet, they find no relation between repeated interactions and contract type. Johnson et al. (2002) examine inter-firm relationships in former Eastern Bloc countries where enforcement is consistently weak but provides a fall back point for relational contracts. Gil (2013) finds that distributors in the Spanish movie industry combine formal and relational contracts to achieve optimal outcomes. Gil and Marion (2013) and Gil and Zanarone (2015) provide a more complete summary of this literature.

The above studies are limited to examining either the choices of a variety of agents within a single legal structure or to the choices of a single agent across a variety of legal structures. We build on this previous work by examining contracts not only across a variety of institutional enforcement mechanisms but also across a variety of buyer-seller pairs. Utilizing this variation across both vectors, we analyze how formal contracts interact with relational contracts and how individual contract choice varies within a given institutional framework. Our conclusions are thus generalizable to a broader set of contracting environments than previous studies.[1]

A second body of literature comprises studies that attempt to empirically examine the determinants of contract choice using a discrete choice model. While Corts and Singh (2004) look at the choice between formal and relational contracts, most of these studies examine contract choice within a contract class. Contract choice is between several types of formal contracts or several types of relational contracts, not between formal and relational contracts. These studies focus on the role of risk preferences, bargaining power, and *ex post* discretion within a given contracting environment. Examples include CEO employment agreements (Gillan et al., 2009), land tenure arrangements in Renaissance Tuscany (Ackerberg and Botticini, 2002) and Madagascar (Bellemare, 2006), and irrigation contracts in India (Aggarwal, 2007). In these contexts, the most common determinant is the risk preferences of the contracting parties, with contracts distinguished by who bears the majority of risk. In this sense, they align with the tradition of Grossman and Hart (1983) in examining the trade-off between incentives and risk. We connect this strand of literature with the broader insights of relational contract theory by modeling the market for groundwater irrigation as one in which the existence of enforcement institutions is not consistent across the population. In this environment, contract choice is not simply between varieties of formal or relational contracts but between a relational contract that relies on unverifiable high-quality information and a formal contract that relies on verifiable but low-quality information.

The final body of literature we contribute to is that on groundwater irrigation contracts. The majority of this literature examines market structure and tests for the existence of market power (Shah et al., 1993; Jacoby et al., 2004; Palmer-Jones, 2010; Ansink and Houba, 2012). However, some studies investigate the transactional relationships within the market. These studies often uses the language of contract theory to motivate descriptive empirical analysis of groundwater markets. Examples include bilateral bargaining (Kajisa and Sakurai, 2003), relational contracting (Kajisa and Sakurai, 2005), moral hazard and risk sharing (Aggarwal, 2007), and enforcement by social institutions in the shadow of a formal legal system (Rahman et al., 2011). Although these studies

[1] There is an interesting and rapidly growing literature on relational contracts in developing countries. Recent examples include Macchiavello and Morjaria (2015, Macchiavello and Morjaria). However, these studies tend to focus on institutional arrangements where formal contracting is not an option. Our environment is broader in that individuals can choose relational or formal contracts.

use principal-agent terminology, few have developed econometric tests based on comparative static results generated by theoretical models. Such atheoretical approaches can result in incomplete analysis, circumscribing the generalizability of empirical insights, and limiting the value of policy recommendations. The recent work by Giné and Jacoby (2015) proves an exception to this trend.[2] The authors develop a contract-theoretical model of groundwater transactions to examine the trade-off between relational and formal contracts within a given institutional environment. Our work is most closely related to Giné and Jacoby (2015), but we go beyond their work by examining contract choice across a number of different enforcement institutions.

The use of contract theory to develop empirical tests and drive analysis has been lacking in studies of agricultural products in general and groundwater markets specifically (Wu, 2014). This article contributes to filling that gap in the literature by using relational contract theory to help understand contract choice and enforcement issues. We also investigate contract choice across several types of institutional enforcement. By better understanding why certain types of contracts are adopted and how contracts are enforced, we provide a clearer picture of the current market structure in Bangladesh. Furthermore, by adapting existing theoretical models to the specifics of the market for groundwater irrigation, we provide generalizable comparative static results that can direct future empirical work in similar environments.

2 Institutional Details

The market for groundwater in Bangladesh is one of imperfect competition (Mukherji, 2004). A limited number of well owners sell water to a larger number of water buyers. Irrigation channels in Bangladesh are usually unlined and uncovered, increasing the transportation cost of water and further limiting a buyer's pool of potential sellers to nearest neighbors. Offsetting the power of water sellers 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. Discontinuous

[2] Another study that attempts to model the behavior of buyers and sellers in the marketplace 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.

landholding, combined with high water transportation costs, mean that 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 limits an owner's market power. We find that the price of water does not vary greatly within a village and interpret this as evidence of spatial integration in village water markets. Despite an absence of price discrimination within a village, contracts for water vary within villages. These institutional details present an attractive environment within which to study how village-level governance affects the adoption of relational and formal contracts.

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 choosing to grow a crop during the *Boro* season or not. Since 99 percent of land cultivated in the *Boro* season is rice (VDSA, 2013) the choice to plant a crop in this season implies that the crop chosen will be rice. Having chosen to grow rice, the water buyer than chooses a water seller with which to contract. In our data set, 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 of buyers responded that a seller's reputation in the village or the buyer's previous relationship with the seller was the most important factor in choosing a water seller.

Once a buyer has chosen a seller to supply irrigation to the parcel in question, the buyer and seller negotiate over the type of contract. Contracts are agreements between a water buyer and a well owner concerning the quantity of and price for water delivery to a farmed parcel. Note that the water buyer may own a well himself but, due to transportation costs from his own well to the parcel in question, chooses to purchase water for that parcel. Water buyers maximize profits across the parcels they farm. In contrast, water sellers maximize profits from selling water.[3] Thus, each contracting party has different incentives. Water buyers try to minimize input costs given a chosen quantity/quality for the input. Water sellers try to minimize their own costly action (delivering

[3]Since well owners are almost always water buyers on at least one parcel, well-owning households are actually concerned with maximizing total household profits - the sum of profits from crop production and water sales. Strictly speaking this does not mean that households maximize profits from crop production and maximize profits from water sales. Rather, since they may be purchasing water from a household they are also selling water to, albeit on different parcels, they maximize joint profit from the two ventures. To simplify the analysis we focus on households that purchase water from but do not sell water to a given household.

the water input), while maximizing the revenue from the contract. Since each party has different objective functions, incentive alignment problems may exist.

We observe three different types of groundwater contracts in Bangladesh: fixed charge, two-part tariff, and output share. These three form a subset of the irrigation contracts discussed by Shah (1993) in his systematic study of groundwater markets in developing countries. The observed contracts are differentiated from each other by variation in three contract characteristics. These characteristics are 1) timing of payment, 2) contingency of payment, and 3) which party retains discretion at the end of the contracting period.

A fixed charge contract is one in which the water buyer makes a onetime cash payment to the water seller at the beginning of the growing season. Prior to payment being made, both parties agree to the amount of water to be delivered throughout the season. Payment is made with the *ex ante* assumption that the agreed upon amount of water will be delivered throughout the season. However, the water seller has *ex post* discretion in fixed charge contracts. Once the upfront payment is made, the water seller has little incentive to deliver the agreed upon amount of water and, since verifying adequate water delivery throughout the growing season is expensive, the water buyer has no recourse in the case of contract violation by the seller.

A two-part tariff contract is one in which the water buyer makes a onetime cash payment to the water seller at the beginning of the growing season for access to the seller's pump throughout the season. When the water buyer desires to use the pump, he pays the seller the marginal cost of the water, which in most cases is the cost of the diesel for the pump. Once the growing season has commenced, the two-part tariff operates like a piece rate contract, with buyers paying sellers at the time of delivery and only paying for water delivered. Since it is expensive for third parties to verify throughout the growing season that the agreement made at the beginning of the season was met (the primary concern being that the water buyer received access to the pump when desired), two-part tariffs are not third-party verifiable. However, since the two-part tariff mimics a piece rate contract in season, neither party has any discretion to deviate from the contract terms.

An output share contract is one in which 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. While in the previous two contracts payment was made contingent on delivery of water, in the output share contract payment is made contingent on crop production. Since crop output is realized in a single time period, as opposed to water delivery, which occurs in numerous time periods, the cost of verifying crop output contracts is significantly less than in verifying contracts based on water delivery. This makes contracts based on crop output third-party verifiable, at least by village institutions. If village institutions are willing to verify output share payment, then we can consider such a contract village-level enforceable and, as a result, no party has *ex post* discretion to deviate from the agreed upon terms. However, if village institutions are unwilling to verify crop share payment, then the water buyer has *ex post* discretion in the contract. Once water is delivered and harvest arrives, the water buyer has little incentive to deliver the agreed upon amount of crop output.

To summarize, regarding the timing of payment, fixed charge payment occurs at the beginning of the season, two-part tariff throughout the season, and output share at the end of the season. Payments for both fixed charge and two-part tariff contracts are made contingent on the delivery of water, which, due to the timing of delivery, is unverifiable by third parties. By contrast, payment under the output share contract is contingent on the level of crop production, a noisy but third-party verifiable signal for water delivery. Finally, under fixed charge contracts the water seller retains all the discretion while under two-part tariffs the discretion is balanced between parties. Discretion under output share contracts depends on village-level institutions. If village institutions refuse to enforce output share contracts then the water buyer retains all the discretion. However, if village institutions enforce output share contracts, and punishment is strict enough to deter breach, neither party retains discretion. This institutional arrangement allows us to explore how different forms of governance affect contract choice. We are also able to explore the role bargaining power and *ex post* discretion play within a given governance structure.

3 Theoretical Framework and Testable Hypotheses

This section presents a model of relational contracting first developed by Baker et al. (1994, 2002) and expanded by Dixit (2004). We adapt the model to the institutional details of groundwater irrigation in Bangladesh and derive useful comparative static predictions for empirical testing.

3.1 The Economic Environment

We consider a repeated contracting game between a single water buyer (the principal) and a single water seller (the agent). Given the institutional environment, our repeated contracting game begins after the matching of buyers and sellers. In this way, the contract choice decision is sequential and separate from the matching decision. This is the same economic environment modeled by Baker et al. (1994). In each period, the agent undertakes several actions in the delivery of water to the principal. These actions are unobservable and may include, but are not limited to, maintenance of the pump, delivery of a specific volume of water (adequacy), and delivery of water at a specific time (reliability). We represent these agent actions with the n-dimensional vector $\mathbf{a}$. The agent incurs a personal cost which, with no loss of generalizability, we approximate with the quadratic function $c(\mathbf{a}) = \frac{1}{2}\mathbf{a}'\mathbf{a}$.

The agent's unobservable action determines the outcome y for the principal. In contracting with the agent, the principal is solely interested in the delivery of what they deem to be sufficient water. Therefore, y takes only two values. If the agent delivers sufficient water, $y = 1$. If the agent fails to deliver sufficient water, $y = 0$. The probability of success is

$$\Pr(y = 1|\mathbf{a}) = \mathbf{y}'\mathbf{a} \tag{1}$$

where $\mathbf{y}$ is an n-dimensional vector of the marginal products of agent action with respect to the outcome, y. Following Baker et al. (2002), we assume all parameters are such that probabilities fall in the requisite range $(0, 1)$.

The outcome y is observable by both the principal and agent (i.e., is common knowledge) and therefore can be contracted on by the principal and the agent. However, such a contract must be relational because y is not verifiable by a third-party and therefore it is not third-party enforceable. This is because water is delivered throughout the growing season. Assume for a moment that a water buyer determines that sufficient water for his parcel is y_s. A water seller could deliver y_s, as agreed, but the water buyer could claim the contract was actually for $\overline{y}_s > y_s$. Similarly, a water seller could deliver $\underline{y}_s < y_s$ while claiming to have delivered y_s. Since the delivery of sufficient water requires periodic delivery of water throughout the growing season, a third-party cannot, at the conclusion of the contract, accurately determine if y_s was delivered. Since a third-party cannot verify if y_s was delivered that third-party cannot rule in a dispute on y.

Despite the inability to verify y, the agent's actions affect a second performance measure, x, which is observable and publicly verifiable. In the case of groundwater contracts, this publicly verifiable signal is crop output. We normalize x to take a value between 0 and 1 such that

$$\Pr(x|\mathbf{a}) == \mathbf{x}'\mathbf{a} \tag{2}$$

where $\mathbf{x}$ is an n-dimensional vector of the marginal product of agent action with respect to the performance measure, x.

The compensation package is based on three components: an unconditional salary S, a third-party enforceable performance payment ξ based on x, and a self-enforcing performance payment η paid if $y = 1$. The timeline of events within each contracting period are as follows. First, the principal offers the agent a compensation package based on S, ξ, and η. Second, the agent decides to accept or reject. If rejected, the principal and agent default to a purely formal contract. Third, if accepted, the agent chooses an action with cost $c(\mathbf{a})$. Fourth, the principal and the agent observe the realization of the agent's contribution to y and, if necessary, the realization of x. Finally, the principal chooses whether to pay the unenforceable performance payment η. The principal also pays the promised fixed payment and third-party enforceable performance payment as specified in the contract.

If the agent believes the principal will honor the unenforceable performance payment, then the agent seeks to maximizes his expected payoff

$$\max_{\mathbf{a}} U = S + \xi\mathbf{x}'\mathbf{a} + \eta\mathbf{y}'\mathbf{a} - \tfrac{1}{2}\mathbf{a}'\mathbf{a}\,. \tag{3}$$

With this compensation scheme we can represent the three types of contracts observed in Bangladesh.

- **Fixed charge** $S > 0$, $\xi = 0$, $\eta = 0$.

- **Two-part tariff** $S \geq 0$, $\xi = 0$, $\eta > 0$.

- **Output share** $S = 0$, $0 < \xi < 1$, $\eta = 0$.

Regardless of the type of contract, the agent will seek to choose his first best action by equating the marginal product of effort with the marginal cost. Solving for the optimal action leads to $\mathbf{a}^* = \xi\mathbf{x} + \eta\mathbf{y}$.

Turning to the principal, the value of the contract accrues to the principal from the sufficient delivery of water by the agent. We represent the principal's payoff from the contracting relationship as

$$V = \mathbf{y}'\mathbf{a} - (S + \xi\mathbf{x}'\mathbf{a} + \eta\mathbf{y}'\mathbf{a}) - v_0 \tag{4}$$

where V is the value of sufficient water to principal, v_0 is the principal's outside option, and all other terms are as previously defined. While ultimately the principal is interested in maximizing profit from rice production, the contracting relationship governs only the delivery of water. If one were to examine the production function for rice, equation (4) would be a factor input equation in that production function.

The contracting problem for the principal can be explicitly stated as:

$$\max_{(S,\xi,\eta)} \quad \mathbf{y}'\mathbf{a} - (S + \xi\mathbf{x}'\mathbf{a} + \eta\mathbf{y}'\mathbf{a}) - v_0 \tag{5}$$

$$\text{s.t.} \quad \xi\mathbf{x} + \eta\mathbf{y} \geq \mathbf{a} \tag{6}$$

$$S + \xi\mathbf{x}'\mathbf{a} + \eta\mathbf{y}'\mathbf{a} - \tfrac{1}{2}\mathbf{a}'\mathbf{a} \geq u_0 \tag{7}$$

where equation (6) is the agent's incentive compatibility constraint and equation (7) is the agent's participation constraint, with u_0 as the agent's outside option.[4]

[4]To simplify the subsequent analysis and allow us to focus on the issue of enforcement and verifiability, we assume the principal satisfies both the agent's incentive compatibility constraint and participation constraint with equality.

3.2 The Benchmark Contract

To simplify the analysis, we first outline a benchmark scenario in which everything is observable and third-party enforceable by a third-party. Because everything is enforceable, repetition is not needed because self-enforcement is not needed, and we can analyze the problem as a one-shot game. Starting with the agent's optimal action level, $\mathbf{a}^* = \xi\mathbf{x} + \eta\mathbf{y}$, we can substitute this value back into the agent's objective function. After simplification, this yields

$$U^* = S + \tfrac{1}{2}(\mathbf{x}'\mathbf{x}\,\xi^2 + 2\mathbf{x}'\mathbf{y}\,\xi\eta + \mathbf{y}'\mathbf{y}\,\eta^2). \tag{8}$$

We can simplify further by choosing units such that $\mathbf{x}'\mathbf{x} = 1 = \mathbf{y}'\mathbf{y}$ and $k = \mathbf{x}'\mathbf{y}$. Geometrically, k is the cosine of the angle between vectors $\mathbf{x}$ and $\mathbf{y}$. By the Cauchy-Schwarz inequality we can show $k^2 \leq 1$. Economically, k is the correlation between the marginal effects of $\mathbf{a}$ on x and y, and therefore is a measure of the accuracy of the verifiable information x in revealing the unverifiable information y. We then rewrite the agent's maximized utility as

$$U^* = S + \tfrac{1}{2}(\xi^2 + 2k\xi\eta + \eta^2). \tag{9}$$

The contracting problem can be simplified substantially by substituting the agent's maximized utility in equation (9) and the agent's optimal action level into the principal's objective function given in equation (5). This yields,

$$\max_{(\xi,\eta)} \; (k\xi + \eta) - \tfrac{1}{2}(\xi^2 + 2k\xi\eta + \eta^2) - u_0. \tag{10}$$

Since we are assuming that both outcomes are fully observable, and therefore both bonus payments are third-party enforceable, the first order conditions for maximization are $k - \xi - k\eta = 0$ and $1 - k\xi - \eta = 0$. The solutions to these conditions are $\xi^* = 0$ and $\eta^* = 1$ when $k \neq 1$.[5] Intuitively, if crop output is not perfectly correlated with water delivery, and both bonuses are enforceable, the principal will make payment based directly upon the outcome of interest (y). Solving for the

[5] If $k = 1$ there is no unique solution and both bonuses can be used interchangeably.

maximized value to the principal of the benchmark contract we get $V^B = \frac{1}{2} - u_0 - v_0$.[6]

3.3 The Purely Formal Contract

We now turn to the case where contracting is only possible based upon the verifiable information x. In this case $\eta \equiv 0$ and the principal selects ξ to maximize equation (10). The simplified maximization problem is

$$\max_{(\xi)} \quad k\xi - \frac{1}{2}\xi^2 - u_0 - v_0. \tag{11}$$

which yields $\xi^* = k$ as the solution to the first order condition. The size of the bonus, ξ, is increasing in the informativeness of the external signal, k. Intuitively, as k becomes a more accurate measure of the outcome of interest, the principal increases the size of the bonus based on the signal in order to better motivate the actions of the agent. Since contracting parties do not, in principle, care if the verifiable information x is positively or negatively correlated with y, what matters is not the sign of k but the strength of correlation (i.e., k's informativeness). Solving for the maximized value to the principal of the purely formal contract we get $V^{\text{FRM}} = \frac{1}{2}k^2 - u_0 - v_0$.[7]

3.4 The Relational Contract

Up to this point, because all contracts were based on observable measures and therefore bonus payments were credible, there was no need to consider the dynamic or repeated nature of the contracting game. In order for contracting parties to rely on the unenforceable or relational bonus, it must be the case that the principal's promise to pay the unenforceable bonus is credible. The tendency will be for the principal to renege on paying the bonus η since it is based upon non-verifiable output, y, and is therefore not third-party enforceable. If the principal does renege on the bonus, the agent can choose to punish the principal by only ever engaging in the purely formal

[6] If $\frac{1}{2} \leq u_0 + v_0$ than the value of the contract is less than the value of the outside options and parties would refuse to contract. Therefore, we assume that $\frac{1}{2} > u_0 + v_0$.

[7] If $\frac{1}{2}k^2 \leq u_0 + v_0$ than the value of the formal contract is less than the value of the outside options. In this case, formal contracts would not operate as a default option for relational contracts. In discussions with households, most said they would rather revert to a formal contract with their current water seller than search for a new contracting partner. Therefore, we assume that $\frac{1}{2}k^2 > u_0 + v_0$.

contract.[8]

For the use of the unenforceable bonus to be self-enforcing it must be the case that the value to the principal of the one-time gain from reneging on paying η is less than the loss from using the formal contract in each future period. This self-enforcement constraint is

$$\frac{\delta}{1-\delta}\left(V^{\text{RLT}} - V^{\text{FRM}}\right) \geq \eta \mathbf{y}'\mathbf{a} \tag{12}$$

where V^{RLT} is the value to the principal of using the relational contract and δ is the discount rate of the principal.

Adding the self-enforcement constraint to the list of constraints on equation (5), and multiplying the payoffs by $1-\delta$ to express them as per-period averages, we can write the fully dynamic relational contracting problem.[9]

$$\max_{(S,\xi,\eta)} \quad (1-\delta)\left[\mathbf{y}'\mathbf{a} - S - \xi\mathbf{x}'\mathbf{a} - \eta\mathbf{y}'\mathbf{a}\right] + \delta V^{\text{RLT}} \tag{13}$$

$$\text{s.t.} \quad (1-\delta)\left[\xi\mathbf{x} + \eta\mathbf{y} - \mathbf{a}\right] + \delta U^{\text{RLT}} \geq \delta U^{\text{FRM}} \tag{14}$$

$$(1-\delta)\left[S + \xi\mathbf{x}'\mathbf{a} + \eta\mathbf{y}'\mathbf{a} - (1/2)\mathbf{a}'\mathbf{a}\right] + \delta U^{\text{RLT}} \geq U^{\text{FRM}} \tag{15}$$

$$(1-\delta)\left[\mathbf{y}'\mathbf{a} - S - \xi\mathbf{x}'\mathbf{a} - \eta\mathbf{y}'\mathbf{a}\right] + \delta V^{\text{RLT}} \geq (1-\delta)\left[\mathbf{y}'\mathbf{a} - S - \xi\mathbf{x}'\mathbf{a}\right] + \delta V^{\text{FRM}}. \tag{16}$$

Constraints (14) and (15) are the agent's incentive compatibility and participation constraint. Here U^{RLT} and U^{FRM} are the continuation values of the relational and formal contract to the agent. Constraint (16) is the principal's self-enforcement constraint.

With symmetric information the optimal contract is stationary in that the same optimal contract is offered in every period (Levin, 2003; Halac, 2012). This allows the fully dynamic problem to be reduced to essentially a static optimization problem. The first order conditions for the static optimization problem are $k - \xi - k\eta = 0$ and $1 - k\xi - \eta - \mu r = 0$ where $\mu = \lambda/(1+\lambda)$ and λ is the Lagrangian multiplier. The solutions to these conditions are the following optimal values for the

[8]Since $V^B > V^{\text{FRM}}$ when $k < 1$, the principal prefers the benchmark contract.

[9]Note that v_0 need not appear in the objective function since it appears in the maximized value function for the formal contract (V^{FRM}).

enforceable and unenforceable payment:

$$\xi^* = \mu r k/(1-k^2) \tag{17a}$$

$$\eta^* = (1-k^2-\mu r)/(1-k^2) \tag{17b}$$

Assuming that the agent's incentive compatibility constraint and participation constraint are aways satisfied with equality, this gives two relevant solutions.[10] The first occurs when $\mu = 1$ and $\delta \geq (1-k^2)$ and is equivalent to the purely formal contract solved for in section 3.3, where $\xi = k$ and $\eta = 0$. Because the principal's self-enforcement constraint is binding and the accuracy of the signal k is relatively strong, the principal forgoes use of the relational contract for exclusive use of the formal contract. In the context of groundwater irrigation, this is the output share contract.

The second solution is when the relational contract is self-enforcing. This occurs when $\mu = 0$, meaning the principal's self-enforcement constraint (16) is non-binding. In this case $\xi = 0$ and $\eta = 1$. The water buyer forgoes use of the verifiable low-quality information for exclusive use of the unverifiable high-quality information. Such contracts include fixed charge and two-part tariff contracts as special cases.

3.5 Testable Implications

We examine two comparative static results from the relevant solutions to the relational contracting model. These results provide information on how preferences over relational and formal contracts change as 1) the accuracy of verifiable information changes and as 2) the severity of third-party punishment changes.

The first comparative static result is how η and ξ change as the signal accuracy of k changes.

[10] For ease of exposition in the text we only provide solutions that correspond to our three observed contract types. Complete worked solutions, including second-best solutions, can be obtained from the authors upon request.

Taking the derivatives of equations (17a) and (17b) with respect to k gives

$$\frac{\partial \xi}{\partial k} = \frac{\mu r(k^2+1)}{(1-k^2)} \tag{18a}$$

$$\frac{\partial \eta}{\partial k} = -\frac{2\mu r k}{(1-k^2)} \tag{18b}$$

The relationship between k and ξ is unambiguous: ξ is at a minimum when $k = 0$. When k is a very noisy signal (i.e., $k = 0$) the verifiable information, x, provides no information on the delivery of sufficient water, y. All else being equal, contracting parties will prefer to forgo the use of formal contracts based on ξ when k is zero. The relationship between k and η is also unambiguous: η is at a maximum when $k = 0$ and $\eta \to -\infty$ as $|k| \to 1$. All else being equal, contracting parties will prefer to use relational contracts based on η when k is near zero. This leads to the following:

Test 1 *Relational contracts are more likely when $|k|$ is close to 0 while formal contracts are more likely when $|k|$ is close to 1.*

The second comparative static result regards how η and ξ change as the severity of third-party punishment for violations of formal contracts changes. Returning to the maximized value of the formal contract ($V^{\text{FRM}} = \frac{1}{2}k^2 - u_0 - v_0$), as the severity of punishment for defection on formal contracts increases, the outside option (v_0) becomes less attractive, increasing the value of V^{FRM}. A larger payoff to the principal on the formal contract tightens the self-enforcement constraint (16), decreasing the value of the relational contract relative to the formal contract. This leads to the following:

Test 2 *Relational contracts are more likely when third-party punishment of formal contracts is lax while formal contracts are more likely when third-party punishment is severe.*

4 Data Description

To conduct our empirical analysis, we use household data from rice-growing villages in Bangladesh. The data covers 960 households from 96 villages who were surveyed immediately after the 2013

Boro (dry) season to collect information on contracts for groundwater irrigation used in that season. The survey also collected information on previous contracting practices, village-level contract enforcement, and sanctions for contract violations. Households were randomly selected while villages were selected using a stratified random sampling method to ensure a representative sample of irrigated agriculture in Bangladesh.

Households were asked a range of baseline questions regarding income, land and asset ownership, and agricultural productivity. Since the survey was specifically designed to study groundwater contracting, it provides us with detailed information on contract history, availability, choice, and price. Data on household experience with or perceptions of enforcement and punishment mechanisms was also collected. Since not every household has experience of contract violation, village-level surveys were also conducted to gain understanding of available contracts, recourse for contract violations, and village governance and punishment mechanisms.

Among surveyed households 20 to 30 percent owned wells and did not purchase water for the majority of their parcels. The remainder were purchasers of irrigation on all farmed parcels. In our analysis we use the subset of 728 households that purchased irrigation and focus on the contract used to secure irrigation for their largest parcel in the current *Boro* season.

4.1 Contract Type

Households were asked what type of contract they use (and have used previously) to secure groundwater irrigation. In the 2013 season, households used three types of contracts for groundwater: fixed charge, two-part tariff, and output share (see Table 1). Fixed charge is the most common contract type, used by 325 households, and two-part tariff contracts are the second most common, used by 253 households. While fixed charge contracts are commonly used in all political divisions, never accounting for less than twenty percent of contracts, two-part tariff use varies by division. Only 3 percent of contracts in Rajshahi are two-part tariffs while in neighboring Rangpur 51 percent of contracts are two-part tariffs. Output share contracts are the least common, used by 150 households. Like two-part tariffs, share contract use varies by division. They are common in Dhaka and Rajshahi but uncommon in the three other divisions. Thus, in Bangladesh, contract choice appears to be, in part, a function of the market of residence.

4.2 Accuracy Signal

Empirical measures of the correlation between the marginal effects of agent action ($\mathbf{a}$) on water delivery (y) and observable crop output (x) are difficult to come by. Such a measure needs to be observable to both buyer and seller and must account for both the seller's performance in delivering water and the buyer's performance in growing crops. Additionally, the measure needs to be exogenous to the contract. Thus measures of a seller's performance in delivering water (frequency of visits to the parcel, number of irrigation applications) are not viable signals because they do not account for the performance of the buyer and are endogenous to contract choice. Nor is a measure of the buyer's ability in growing crops (production efficiency) a viable signal because it does not account for the performance of the seller and is endogenous to contract choice. What is needed is a variable exogenous to the contract as well as to both seller and buyer action while being informative regarding the seller's contribution to crop output.

We use a measure of soil quality for our proxy of signal accuracy. Prior to contracting, both seller and buyer can observe soil quality by the color and consistency of the soil. With this information the seller knows that, given his level of action, better soil quality will be associated with better crop output regardless of the buyer's abilities as a farmer. Thus, soil quality can be observed by both seller and buyer and is exogenous to contract choice. Additionally it accounts for both buyer and seller actions in that better quality soil will reduce the variance of crop output regardless of seller or buyer actions.

Besides these empirical motivations for using soil quality as our proxy for signal accuracy, there is theoretical justifications for our choice. The role of k in the contracting relationship is as a measure of the noise in the formal contract. We can think of k in either of two ways: as a reduction in the variance of crop output or as a version of the informativeness principle. The role of soil in reducing variance in crop output can be illustrated using the formula for the correlation coefficient, where $k = \frac{\mathrm{Cov}\,(y,x)}{\mathrm{Var}\,(x)\mathrm{Var}\,(y)}$. Good soil quality reduces the variance of crop output (x) for a given level of water input (y), increasing the value of k. With poor soil, the water seller might provide exactly the right amount of water when necessary but the variance of output will be large and thus poor quality soil is a poor signal of his performance. Regarding soil as an informative signal, the informativeness principle claims that any additional information, however imperfect, can be used to improve outcomes in formal contracts Holmstrom (1979). When soil quality is extremely poor ($k = 0$), crop yield provides no information regarding the delivering of water. When soil quality is extremely bad, water does not matter much. As soil quality increases ($k \to 1$), the noise in the contracting relationship is reduced. Better soil reveals (on the margin) information about agent action in delivering water. Since soil quality is informative regarding the effectiveness of the water input, is observable by both parties, and is exogenous to contract choice, we believe it is a good choice for a measure of the correlation between the marginal effect of water delivery on crop output.

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, standard, or good. By construction, most soil is of standard quality (57 percent) while 19 percent of parcels have good quality soil and 24 percent of parcels have poor quality soil (see Panel A in Table 2). To verify that our soil quality rankings are accurate, we run a regression of crop output on inputs using a parsimonious product function, with indicator variables for each soil type. We also estimate the model with division-level fixed effects and upazila-level fixed effects to account for potential unobserved regional differences in production technologies. Results from all three regressions are presented in Table 3. While the coefficient on standard quality soil is not significant the coefficient on good quality soil is positive and significantly improves output compared to poor quality soil. An important result of our production regressions is that contract type is not related to crop output. Additionally, the rest of the inputs in the production function have the expected sign. The exception is the labor input, which is negative, although Rahman (2014) finds a similar result for *Boro* rice production in Bangladesh.

4.3 Village Governance

Our data set contains both household and village-level information on contract enforcement and punishment. Given that not all households have experienced contract violation, we prefer the village-level data on enforcement and punishment. In each village a focus group discussion was conducted with seven to ten leaders of the village to determine what types of parties enforce contracts and what types of punishments are used by those parties when contracts are violated.

In Bangladesh we found four options for resolving contract disputes (see Panel A in Table 4). The first is reliance on resolution between the contracting parties without recourse to third-party arbitration. This type of contract resolution is necessary in villages that do not provide an enforcement institution for formal contracts. The second option is reliance on a single individual, often a relative, trusted friend, community leader, or religious leader. The disputants appeal to this individual who then arbitrates the dispute and determines punishment. The third option is a group of village elders or community leaders. The elders together discuss and rule on the dispute. The fourth option, which is rarely invoked, is the official court system.

The data also contains information on what types of punishments are used by each arbitrating party. We categorize these into three types of punishment, ranked from least severe to most severe. The least severe punishment is when the arbitration party devolves responsibility for determining punishment to the disputants. 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 Bangladesh is social ostracism. This punishment 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.

Both arbitration parties and punishment types differ from division to division (see Panels B and C in Table 4). Reliance on contracting parties to resolve their own disputes is the most common practice in all divisions, except for Chittagong. Resolution by a group of elders is second most common in all divisions. Economic fines as a form of punishment are more common in Chittagong and Khulna while social ostracism is more common in Rajshahi and Rangpur. In Dhaka, the punishment method is balanced between the two forms.

In our empirical analysis we use a binary indicator for each type of punishment to measure if more severe punishment results in fewer relational contracts. Our base case is no third-party enforcement.

4.4 Household Characteristics

A key feature of relational contracts is that they rely on repeat trading for enforcement (Corts and Singh, 2004; Macchiavello and Morjaria, Macchiavello and Morjaria). The degree to which relational contracts are self-enforcing is therefore dependent on how much contracting parties value the future. To measure this we estimate a household's subjective discount rate using data on intertemporal trade-offs collected via a simple choice experiment.[11] Additionally we include wealth per capita as a proxy for the individual's risk preference on the assumption that a larger asset base indicates a preference for the future and/or lower risk aversion (see Panel B in Table 2).

We also control for bargaining power in the contracting relationship and, therefore, the inability of a party to choose their preferred contract type. To accomplish this, we introduce four variables that measure the preexisting relationship between buyer and seller. First, we use a binary indicator for whether or not the water seller has some degree of social power over the water buyer. Households were asked if the water seller was a leader in the village, if the seller's social rank was higher, and if the seller can harass the buyer with impunity were the buyer to complain about the contract. The variable for seller's social power takes a one if the buyer responded "yes" to any of these questions. In total 46 percent of households contract with sellers who have social power over them. Second, we measure if the buyer and seller are partners in any business ventures. In total, 48 percent of water buyers have some sort of additional business dealing with the water seller. Third, we include a binary variable equal to one if parties are related to each other or of the same social caste.

[11]See Appendix A for a discussion of how we measure discount rates.

Contracting with a relative of some sort is relatively uncommon in the data with only 36 percent of households contracting with a relative or caste member.[12]

4.5 Well Characteristics

Because the choice of contract may be influenced by the type and ability of the well that irrigates the parcel, we include several measures of well characteristics (see Panel C in Table 2). These include indicator variables for whether or not the well was a shallow tubewell, a deep tubewell, or a low lift pump. The majority of wells in the sample (82 percent) are STWs while 15 percent are DTWs. Only three percent of households received irrigation via low lift pumps.

Including the type of well that supplies water is important because STWs and DTWs differ along several lines that could determine contract choice. STWs tend to be owned by individuals while DTWs tend to be owned by groups of individuals. Negotiating over contracts with a group instead of an individual may determine what contracts are chosen. Since ensuring self-enforcement should be easier when dealing with a single well owner than with a group, it seems likely relational contracts are more common with STWs. DTWs have larger command areas than STWs and therefore provide water to more buyers. This could increase competition for adequate and reliable water making contract violation more likely and therefore making formal contracts more common with DTWs.

In addition to the type of well used, we include measures of horsepower, the depth of the water table, the time to irrigate a decimal (1/100 of an acre) of land, and the distance between parcel and well. All of these well characteristics affect the actions of the agent in delivering adequate and reliable water and therefore may be related to contract choice. Wells that are inferior along any of these lines may make agent action more costly, reducing the value of the relational contract, and making defection more likely. Since these variables affect the unit cost of irrigation they also act

[12] In addition to these measures, we examined other measures of bargaining power and contract interlinkages. The two most common interlinkages discussed in the literature on 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 our data only four percent of water-buying households purchase water from their landlord. Regarding loans, 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 our data set and we exclude them from our regression.

as proxies for the price of irrigation, a variable we exclude from our analysis since it is endogenous to contract choice.

5 Empirical Methodology and Results

Our empirical analysis examines contract choice across and within different types of governance structures. Specifically, we test the theoretical implications of our model: how the accuracy of a verifiable signal (*Test 1*) and the existence and severity of enforcement (*Test 2*) change the likelihood that a relational contract is chosen over a formal contract. To simplify our initial analysis, we consider fixed charge and two-part tariffs as one contract type (relational contract) distinct from output share contracts (formal contract).[13] Subsequently, we consider all three contracts as distinct types distinguished by who retains *ex post* discretion. For this analysis we split the data set into villages that provide enforcement and those that do not provide enforcement. The goal is to examine the role bargaining power plays in contract choice within a given governance structure. Since we lack exogenous variation in our variables of interest, the goal is to capture and test the conditional correlation between our variables of interest and contract choice.

5.1 Econometric Model

We conduct our analysis using both a linear probability function (LPM) and a logit function to model the data. The linear probability model takes form:

$$contract_i = \beta_0 + \beta_1 k_i + \beta_2 p_j + \mathbf{Z_i}\delta_\mathbf{1} + \mathbf{W_i}\delta_\mathbf{2} + \nu_\mathbf{i}, \qquad (19)$$

where our dependent variable is a binary indicator that equals one if household i uses a relational contract and zero if it uses a formal contract. Variables of interest are: k the performance measure and p the severity of punishment when formal contracts are violated as determined by village j. We also include idiosyncratic household ($\mathbf{Z}$) and well characteristics ($\mathbf{W}$).

[13] In theory, contracting parties can form hybrid contracts that incorporate the enforceable payment into a relational contract Dixit (2004). However, in practice, we do not observe these types of contracts in the market for groundwater irrigation in Bangladesh.

The benefit of the LPM is that it allows for a larger number of spatial fixed effects than the nonlinear logit estimator. Since enforcement is chosen by the village, it is important to control as much as possible for village-level effects. While we cannot include village-level fixed effects, the LPM allows us to include fixed effects at the upazila-level. Since upazila size is relatively small and each upazila contains only two surveyed villages, the upazila indicators control for weather, political structure, and other unobservable variables between the 48 village clusters. As will be seen below, upazila-level fixed effects have a particularly strong impact on the explanatory power of our regression.

Despite the benefit of including a large number of spatial fixed effects, the LPM often yields biased and inconsistent estimates (Horrace and Oaxaca, 2006). Therefore, we also estimate the following logit model

$$\Pr(\text{RLT } = 1|\mathbf{X}) = \Lambda(\beta_0 + \beta_1 k_i + \beta_2 p_j + \mathbf{Z_i}\delta_\mathbf{1} + \mathbf{W_i}\delta_\mathbf{2}) \tag{20}$$

where all variables are as previously defined. While the LPM allowed us to include 48 upazila-level indicators, the logit only allows us to include fixed effects at the divisional level. This obviously reduces the overall explanatory power of the logit model. However, the sign and significance of our coefficient estimates frequently do not differ across LPM and logit models, though LPM estimates are consistently smaller.

5.2 The Issue of Endogenous Matching

Besides the choice of model, the econometrician must address the potential issue of endogenous matching in the choice of contracts. Aggarwal (2007), in his study of groundwater irrigation contracts in Gujarat, identifies two potential types of endogenous matching. The first is between water buyer and crop choice. Some crops will be relatively less sensitive to adequate and reliable water delivery than other crops. Water buyers who are relatively more risk averse due to unobserved characteristics may choose these crops. Since agent action is relatively less important for these crops, the cost of monitoring is reduced and the buyer may prefer the relational contract. Thus, the choice of crop is potentially endogenous to the choice of contracts. However, in Bangladesh, farmers who have made the choice to grow crops in the *Boro* season (the only season when irrigation is necessary) express no real choice over crop. Rice is by far the dominant crop grown in the season. According to the Village Dynamics Study of South Asia (VDSA, 2013) rice is planted on 99 percent of land in *Boro* season with the remaining one percent divided between wheat, legumes, and vegetables. Given that no non-rice crop accounts for even half a percent of cultivated area, we believe the choice of crop is not endogenous to the choice of irrigation contract.

The second source of potential endogenous matching is between contracting parties. Consider a version of our empirical model in which the water buyer simultaneously determines the contract type and the water seller. In the simplest form, this situation can be modeled as a two-equation simultaneous system:

$$c = \alpha_0 + \alpha_1 s + \mathbf{Z}\alpha_2 + \mathbf{W}\alpha_3 + \nu, \tag{21a}$$

$$s = \gamma_0 + \gamma_1 c + \mathbf{Z}\gamma_2 + \mathbf{M}\gamma_3 + \epsilon. \tag{21b}$$

Here, in the first equation, c is the contract chosen, s is an indicator for the specific seller, and $\mathbf{Z}$ and $\mathbf{W}$ are vectors of buyer and well/project characteristics. In the second equation, $\mathbf{M}$ is a vector of water seller characteristics that directly affect the buyer's choice of seller but do not directly affect the choice of contract.

Note that in this setup there are two related but distinct issues that introduce bias into the estimation procedure. First is the simultaneity issue and second is potential correlation between the error terms. If the decision of contract and seller is made simultaneously by the buyer, endogeneity is induced because of the specification of the second equation. Specifically, ν is not uncorrelated with s. An additional complication arises when ν and ϵ are correlated. This will occur if unobserved project characteristics induce matching of buyers and sellers to projects. This issue of endogenous matching between contracting parties was first addressed by Ackerberg and Botticini (2002).[14]

[14] The empirical contracting literature has developed several methods for dealing with the issue of endogenous matching. Ackerberg and Botticini (2002) and Bellemare (2006), in the context of land tenure contracts, use location dummies as instruments to control for endogenous matching. They argue that contract choice is not a function of the market of residence but does affect the choice of contracting partner and location is thus a valid instrument. Aggarwal (2007), dealing with groundwater irrigation contracts in India, finds that the market of residence does affect contract

The issue of endogenous matching clearly needs to be a concern for empirical work on contract choice because contracting parties are almost never randomly matched with each other. However, as Corts and Singh (2004) note, a necessary condition for the existence of endogenous matching between contracting parties is the simultaneity of the decision of contracting party and contract type. If the water seller is known with certainty before the contract type is determined the system of equations represented by (21a) and (21b) is misspecified. While the buyer and seller will not be randomly matched, the sequential nature of the decision making process (first choose contracting party, then choose contract type) means that the contract choice equation is made conditional on the contracting party. The term s is unnecessary in equation (21a). Omitting seller characteristics from the contract choice equation introduces no omitted variable bias because the seller is known prior to the choice of contract and is not a determinant (either exogenous or endogenous) in the contract choice equation.

While non-random matching surely exists between contracting parties, the timing of decision making in our context means that sellers are chosen prior to contracts. Once a seller is chosen, usually based on proximity of the well to the irrigated parcel, then the two parties negotiate over the contract type.[15] Thus, while buyer characteristics will be correlated with unobserved seller characteristics, those seller characteristics are not relevant to the contract form and we can safely omit them from our regression without introducing bias.

5.3 Results: Relational and Enforceable Contracts

Our initial analysis looks at the correlation between contract choice and the severity of enforcement and the accuracy of a verifiable signal. Results from the LPM and logit models are presented in columns (1) and (2) of Table 5, with average partial effects for the logit presented in columns (1) of Table 6.

choice and is therefore not a valid instrument. As an alternative to location dummies, Aggarwal (2007) exploits the pseudo-panel nature of his data to control for buyer and seller fixed effects. Corts and Singh (2004) develop the most innovative approach to the endogenous matching problem. In the context of offshore oil drilling, they calculate location-specific hypothetical expected values for the endogenous variables and use these as instruments.

[15] Additional justification, if necessary, can be found in our theoretical model, which posits that contract choice is a function of buyer discount rate, signal accuracy, and third-party enforcement, not seller characteristics. Buyers choose payoff values to satisfy seller participation and incentive compatibility constraints but the form that the contract takes is not dependent on seller characteristics.

Regarding the negative correlation between the accuracy of verifiable signal and relational contracts (*Test 1*), soil quality is not significant in the LPM model. However, good soil quality is significant and negative in the logit model. As our theoretical model predicts, increased accuracy of verifiable information in revealing unverifiable information decreases the likelihood of adopting relational contracts. When crop output is strongly correlated with the provisioning of water, the loss of information between the verifiable and non-verifiable action is less, making the verifiability problem less acute, reducing the need to rely on relational contracts.

Turning to the expected negative correlation between the severity of village-level punishment and the adoption of relational contracts (*Test 2*), we find a significant and negative relationship in both the LPM and logit. In our regressions, lack of village-level enforcement is the default case, with indicators for each type of punishment in those villages which provide enforcement. Compared to no enforcement, the use of economic fines and social ostracism reduces the likelihood of adopting relational contracts in both models. As expected, social punishment exerts a larger negative effect than other forms of punishment. Unsurprisingly, we find that village institutions that allow disputants to determine their own punishment (private punishment) are no different than a complete absence of village enforcement when it comes to predicting contract choice. We conclude that, for surveyed households, the existence of severe third-party punishment has a large negative effect on the probability of adopting relational contracts. Thus, households living in villages with more formalized governance structures are more likely to use formal contracts, a less efficient alternative to relational contracts.[16]

To isolate the various effects of our variables of interest on contract choice, we divide our data into two distinct groups based on the existence of village-level enforcement. In the first group we examine contract choice by households that live in villages which provide institutional enforcement

[16]It is possible that the consistently negative and significant coefficients on our punishment variables are the result of an endogeneity bias in our estimates. Such a bias would exist if villages with better soil were richer and therefore had more developed village institutions. In this case, since soil quality is an imperfect proxy for village wealth, village characteristics not captured in this term would result in correlation between our punishment variables and the error term. While this is clearly a plausible story, we find no evidence in our data to support the story. To verify this, we calculate the variance inflation factor (VIF) for the LPM model. The VIFs for the punishment variables are all less than 3 while the VIFs for the soil quality indicators are less then 2. The mean VIF for the regression is 2.73, which is not considerably different than 1 and no where near the threshold value of 10, where collinearity becomes a concern. Additionally, the simple correlation between soil and punish is -0.0039, providing further evidence that better soil is not associated with better village institutions.

of formal contracts. With enforcement, output share contracts can serve as a default option when relational contracts are violated. They can also act as a third-party enforceable alternative to self-enforcing relational contracts if the verifiability problem is not severe. Therefore, we expect our coefficient estimates to share the same sign as our estimates for the population as a whole.[17] We present results from the LPM and logit regressions in columns (3) and (4) in Table 5. Average partial effects for the logit are presented in column (2) of Table 6.

In the second group we examine contract choices by households in villages without any third-party enforcement option. In this setting, output share is no longer a fallback option when relational contracts are violated.[18] This does not mean that output share contracts are no longer used when they are no longer third-party enforceable. Contracting parties might still choose an output share contract for several reasons. One reason is if the water buyer is credit constrained and unable to pay for irrigation prior to harvest. Thus, we expect household wealth to be positively correlated with fixed charge and two-part tariff contracts and negatively correlated with the output share contract. Additionally, all else being equal, output share contracts will be more likely when the correlation between crop output and water input is strong. We present results from the LPM and logit regressions in columns (5) and (6) in Table 5. Average partial effects for the logit presented are presented in column (3) of Table 6.

There are important differences between coefficient estimates in our "village enforcement" and "no village enforcement" settings. Restricting our analysis to the logit specification, we find that good soil quality has a significant and negative effect on relational contracts for both populations. This result matches our theoretical predictions. A more accurate verifiable signal of agent action makes relational contracts less likely in settings where contracts based on the verifiable signal are third-party enforceable. When third-party enforcement does not exist, contracts that rely on a proxy signal of agent contribution to the outcome of interest are more likely to be adopted when that signal is less noisy, all else being equal. Also, we find that, in villages that provide third-

[17] When examining the role of punishment for this subset of villages that provide enforcement, we now must use private punishment as a base case.

[18] Strictly speaking, in this setting all contracts are relational since enforcement of formal contracts is absent and all contracts must be self-enforcing. However, for clarity and consistency we continue to refer to output share contracts as formal and the remaining two contract types as relational.

party enforcement, contracting parties that are of the same family or caste are more likely to adopt relational contracts. This is in contrast to households in villages that provide no third-party enforcement, where point estimates on the caste/kin term are not significant. We conclude that when both relational and formal contracts exist, contracting parties that share a family or caste link are better able to use relational contracts. The pre-existing relationship between contracting parties reduces the likelihood of defection, making self-enforcement of relational contracts easier to achieve. In village settings where no third-party enforcement exists, all contracts must be self-enforcing and so shared kinship/caste is no longer a significant determinant in the choice of contract types.

Summarizing our results, contracts based on a third-party verifiable signal are less likely when that signal is noisy (*Test 1*). Average partial effects for good soil quality are negative and significant across all three population sets. However, in the LPM model, soil quality is not significantly correlated with contract choice in any of the population sets. We conclude that support for *Test 1* is not robust across model specification. We interpret this evidence as suggestive, but not conclusive, of a verifiability problem in the market for groundwater irrigation. Regarding our second comparative static result, we find strong evidence that more severe punishment for violations of formal contracts is negatively correlated with the adoption of relational contracts (*Test 2*). In this case, formal contracts act as substitutes to relational contracts. This result is robust across both contracting environments and model choice. Compared to a base case of no enforcement, formal contracts are more likely when third-party enforcement exists and when that enforcement is more severe. This is true for the population as a whole and for the subset of households that live in villages that provide third-party enforcement.

5.4 Results: Bargaining Power and *ex post* Discretion

We now turn to our second level of analysis in which we view all three contracts as distinct types distinguished by who retains *ex post* discretion. We focus our analysis on two contracting environments: "village enforcement" and "no village enforcement." We rank contracts by who retains *ex post* discretion. Our base case is fixed charge contracts where sellers retain all the discretion.

We contrast the base case with two-part tariff contracts that balance discretion and output share contracts where buyers retain all the discretion. The goal is to determine the role bargaining power plays in contract choice across different types of governance structures.

We expect coefficients on punishment severity and signal quality to be insignificant determinants in the choice between fixed charge and two-part tariff contracts since neither are third-party enforceable. In contrast, we expect coefficients on punishment severity and signal quality to be significant determinants in the choice between fixed charge and output share contracts, but only in an institutional environment where output share contracts are enforceable. Finally, we expect measures of bargaining power in the contracting relationship to matter more than in our previous regressions. This is because our previous analysis grouped fixed charge and two-part tariff contracts together as relational contracts even though they differ in regards to who retains *ex post* discretion. Bargaining power should be noticeably more important in an environment without third-party enforcement since parties have no ability to reduce counter-party risk except through contract choice.

Estimation results for contract choice by households in villages where third-party enforcement is an option are presented in columns (1) and (2) of Table 7. Column (1) compares the choice of the output share contract, where buyers retain discretion, to the choice of the fixed charge contract, where sellers retain discretion. Column (2) compares the choice of two-part tariff contracts, where discretion is balanced, to the choice of the fixed charge contract. As expected, stronger correlation between water input and crop output, as measured by soil quality, increases the likelihood of output share contracts compared to fixed charge contracts. Also, as expected, signal quality is not a significant determinant in the choice between fixed charge and two-part tariff contracts. These results are similar when we consider severity of punishment. More severe punishment increases the likelihood of output share contracts over fixed charge contracts but is not significant in the choice between two-part tariff and fixed charge.

Of interest to the present analysis are the coefficients on our measures of bargaining power in the contracting relationship. We find that seller social power reduces the likelihood of output share contracts compared to fixed charge contracts. This is consistent with our hypothesis, since sellers retain *ex post* discretion in fixed charge contracts while buyers retain discretion in output share contracts. Similarly, we find seller social power reduces the likelihood of two-part tariffs compared to fixed charge since again the seller retains discretion in fixed charge contracts while discretion is balanced in two-part tariff contracts.

Turning our attention to the no-enforcement environment, estimation results for contract choice by households in villages without third-party enforcement are presented in column (3) and (4) of Table 7. Column (3) compares the choice of the output share contract to the choice of the fixed charge contract while column (4) compares the choice of the two-part tariff contract to the choice of the fixed charge contract. We find again that signal quality is correlated with output share contracts but plays no role in the choice between two-part tariffs and fixed charge contracts. We also find that seller social power decreases the likelihood of output share and two-part tariff contracts as sellers with bargaining power seek to retain discretion by using fixed charge contracts.

Summarizing our results from our multinomial logit analysis, we find seller social power increases the likelihood that fixed charge contracts will be used. This empirical result supports our hypothesis that parties with greater bargaining power will adopt contracts that leave them with more *ex post* discretion. These results are robust across contract type and enforcement environment. We also find that signal accuracy and severity of punishment only matter in the choice between output share contracts and fixed charge contracts.

6 Conclusion

In order to examine how different modes of governance influence the decision to adopt relational or formal contracts in the purchase of groundwater irrigation in Bangladesh, we adapted existing models of relational contracting that allowed for variation of enforcement institutions. Consistent with our model's comparative static results, we found empirical evidence of a strong negative correlation between the severity of punishment and the adoption of relational contracts (*Test 2*). We found mixed evidence that relational contracts are preferred when verifiable signals are inaccurate (*Test 1*). Models of the contracting relationships that focus exclusively on incentive alignment or risk management fail to account for this evidence.

In Bangladesh, we observe contracts that not only differ in their enforceability but differ in who retains *ex post* discretion. The role of *ex post* discretion is especially important in villages where no third-party enforcement is provided. This allowed us to analyze contract choice within a given institutional framework. Here we found evidence that supported much of the existing literature on the trade-off between relational and formal contracts. Given an enforcement or no-enforcement environment, contracting parties attempt to balance counter party risk by using bargaining power to force adoption of contracts in which they retain *ex post* discretion.

Our research results in several policy implications. Prime among them is the importance of accounting for the governance structure, or lack thereof, when drafting policies. While reducing risk or aligning incentives is often a concern in contract design, interventions may fail if mechanisms do not conform to the existing institutional framework. In the case of groundwater irrigation in Bangladesh, water management plans that attempt to incentivize conservation must be robust to a variety of enforcement environments. A second policy implication is that attempts to strengthen village or government institutions that enforce contracts may, in the short run, result in sub-optimal outcomes. This is because as third-party enforcement of contracts becomes less costly, self-enforcement of relational contracts, in which payment is contingent on water, becomes more difficult. In this sense, formal and relational contracts are substitutes and attempts to strengthen enforcement without also reducing the verifiability problem may result in reliance on contracts based on low-quality information.

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Table 1: Contract Type by Division

	Fixed Charge	Two-Part Tariff	Output Share	Obs.
Chittagong	62%	35%	3%	35
Dhaka	24%	50%	26%	206
Khulna	59%	32%	9%	148
Rajshahi	49%	3%	47%	172
Rangpur	49%	51%	1%	167
Obs.	325	253	150	728

Source: Authors' calculations from primary data. Rows present percentage of contracts used in a given political division and sum to 100. The far right column presents the total number of contracts observed in a division while the bottom row presents the total number of a given contract observed in the data.

Table 2: Descriptive Statistics of Soil, Household, and Well Characteristics

Panel A: Frequency of Soil Type

	Total	Relational	Formal
Poor Quality (%)	0.24	0.27	0.13
Standard Quality (%)	0.57	0.56	0.63
Good Quality (%)	0.19	0.17	0.24
Obs.	728	578	150

Panel B: Household Characteristics

	Total	Relational	Formal
Discount Rate: 0-6 months (%)	0.70	0.69	0.71
	(0.06)	(0.06)	(0.07)
Wealth Per Cap (100 Tk)	809	818	780
	(857)	(877)	(776)
Seller Has Social Power (%)	0.46	0.48	0.35
	(0.50)	(0.50)	(0.48)
Business Partners (%)	0.48	0.51	0.37
	(0.50)	(0.50)	(0.49)
Relative or Same Caste (%)	0.36	0.39	0.25
	(0.48)	(0.49)	(0.43)
Lacks Alternative Sellers (%)	0.37	0.38	0.31
	(0.48)	(0.49)	(0.46)
Obs.	728	578	150

Panel C: Well Characteristics

	Total	Relational	Formal
Shallow Tubewell (%)	0.82	0.82	0.84
	(0.38)	(0.38)	(0.37)
Deep Tubewell (%)	0.15	0.15	0.15
	(0.35)	(0.35)	(0.36)
Horsepower	10.2	10.3	9.77
	(11.7)	(12.6)	(7.48)
Depth of Water Table (m)	35.9	35.6	37.5
	(19.6)	(19.6)	(19.4)
Time to Irrigate (min/dc)	2.94	3.02	2.64
	(1.99)	(2.06)	(1.73)
Distance Between Plot and Well (m)	224	237	173
	(323)	(334)	(276)
Obs.	728	578	150

Source: Authors' calculations from primary data. The sample is given by all observations in the data, by observations of relational contracts, and by observations of formal contracts. Well characteristics are for wells owned by water seller but utilized by water buyer to irrigate the parcel under contract.

Table 3: Estimation Results of Production Function

ln*(yield)*	(1)	(2)	(3)
Good Soil Quality	0.012	0.012	0.011
	(0.011)	(0.011)	(0.012)
Excellent Soil Quality	0.027**	0.030**	0.034***
	(0.012)	(0.013)	(0.012)
Contract Type	0.011	0.013	−0.003
	(0.011)	(0.012)	(0.013)
ln(Labor)	−0.009**	−0.006*	−0.005*
	(0.004)	(0.004)	(0.003)
ln(Fertilizer)	0.006	0.006	0.007*
	(0.004)	(0.004)	(0.004)
ln(Pesticide)	−0.001	−0.001	−0.002
	(0.002)	(0.002)	(0.002)
ln(Irrigation)	0.031**	0.032**	0.023*
	(0.011)	(0.012)	(0.013)
ln(Other Material)	0.014***	0.017**	0.016**
	(0.007)	(0.007)	(0.007)
Tenure	−0.004	−0.004	−0.006
	(0.009)	(0.009)	(0.009)
Sufficient Frequency	−0.004	−0.003	−0.002
	(0.009)	(0.009)	(0.009)
Sufficient Volume	0.015	0.017	0.020*
	(0.011)	(0.011)	(0.012)
ln(Wealth Per Capita)	0.008	0.009	0.009
	(0.006)	(0.006)	(0.006)
STW	0.017	0.019	0.028
	(0.022)	(0.022)	(0.024)
DTW	0.044*	0.039	0.036
	(0.026)	(0.026)	(0.029)
ln(Horsepower)	−0.005	−0.003	−0.001
	(0.009)	(0.009)	(0.010)
ln(Water Table Depth)	−0.007	−0.006	−0.001
	(0.009)	(0.009)	(0.010)
ln(Irrigation Time)	−0.015**	−0.013*	−0.012
	(0.007)	(0.007)	(0.008)
ln(Plot to Well Dist)	−0.001	−0.001	−0.001
	(0.002)	(0.002)	(0.002)
Fixed Effects	None	Division	Upazila
Observations	728	728	728
R^2	0.07	0.09	0.18

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 47 of the 48 upazilas. Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table 4: Village Level Enforcement Agent and Punishment Method by Division

Panel A: Punishment Method By Enforcement Agent

	None	Private	Economic	Social	Obs.
None	100%	0%	0%	0%	43
Individual	0%	11%	67%	22%	9
Elders	0%	16%	24%	59%	37
Court	0%	0%	100%	0%	7
Obs.	43	7	22	24	96

Panel B: Enforcement Agent By Division

	None	Individual	Elders	Court	Obs.
Chittagong	0%	25%	75%	0%	4
Dhaka	50%	4%	39%	7%	28
Khulna	55%	5%	30%	10%	20
Rajshahi	45%	18%	32%	5%	22
Rangpur	36%	9%	45%	9%	22
Obs.	43	9	37	7	96

Panel C: Punishment Method By Division

	None	Private	Economic	Social	Obs.
Chittagong	0%	50%	50%	0%	4
Dhaka	50%	0%	25%	25%	28
Khulna	55%	0%	30%	15%	20
Rajshahi	45%	5%	18%	32%	22
Rangpur	36%	18%	14%	32%	22
Obs.	43	7	22	24	96

Source: Authors' calculations from primary data collected at the village-level. Panel A presents methods of punishment utilized by each village and the associated village-level enforcing agent. Rows present percentage a punishment method is used by a given enforcement agent and sum to 100. The far right column presents the frequency of each type of enforcement agent while the bottom row presents the frequency of punishment method. Panel B presents the type of enforcing agent adopted by villages within a political division. Rows present percentage of enforcing agent used by villages within a given political division and sum to 100. The far right column presents the total number of villages within a division while the bottom row presents the frequency of each type of enforcement agent. Panel C presents the method of punishment adopted by villages within a political division. Rows present percentage a punishment method is used by villages within a given political division and sum to 100. The far right column presents the total number of villages within a division while the bottom row presents the frequency of each method of punishment.

Table 5: Estimation Results of Contract Choice Equation

	All Buyers		*Village Enforcement*		*No Village Enforcement*	
	LPM (1)	Logit (2)	LPM (3)	Logit (4)	LPM (5)	Logit (6)
Punishment (p)						
Private Punishment	0.131	0.980				
	(0.117)	(1.381)				
Economic Punishment	-0.075^{**}	-1.341^{**}	-0.370^{*}	-2.376^{*}		
	(0.038)	(0.607)	(0.195)	(1.417)		
Social Punishment	-0.155^{**}	-2.681^{***}	-0.254	-3.619^{***}		
	(0.070)	(0.582)	(0.177)	(1.411)		
Accuracy Signal (k)						
Standard Soil Quality	0.035	-0.665	0.021	-0.597	-0.001	-1.046
	(0.025)	(0.422)	(0.030)	(0.472)	(0.034)	(0.990)
Good Soil Quality	0.004	-1.289^{***}	0.050	-1.132^{*}	-0.042	-2.214^{**}
	(0.030)	(0.468)	(0.041)	(0.639)	(0.028)	(1.000)
Household and Well Characteristics						
Discount Rate (0-6 months)	0.187	0.767	0.081	0.935	0.124	0.780
	(0.122)	(2.148)	(0.201)	(2.535)	(0.123)	(4.389)
ln(Wealth Per Capita)	0.032^{**}	0.463^{**}	0.021	0.374	0.042^{***}	0.893^{***}
	(0.013)	(0.202)	(0.018)	(0.248)	(0.015)	(0.295)
Seller Social Power	0.029	0.417^{*}	0.030	0.296	-0.018	0.814^{*}
	(0.017)	(0.250)	(0.024)	(0.300)	(0.015)	(0.480)
Business Partners	-0.003	0.373	0.014	0.342	0.008	0.595
	-0.018	0.263	(0.029)	(0.295)	(0.024)	(0.515)
Same Caste/Kin	0.033^{*}	0.954^{***}	0.048^{**}	1.184^{***}	-0.008	-0.313
	(0.019)	(0.303)	(0.020)	(0.310)	(0.029)	(0.538)
Alternative seller	-0.032^{*}	-0.204	-0.063^{**}	-0.266	-0.024	-0.377
	(0.017)	(0.297)	(0.023)	(0.388)	(0.029)	(0.490)
STW	0.015	2.164^{*}	0.028	2.011^{*}	0.012	-7.889^{**}
	(0.037)	(1.261)	(0.046)	(1.178)	(0.035)	(3.396)
DTW	-0.058	1.834	0.024	2.301^{*}	-0.046	-8.375^{***}
	(0.058)	(1.192)	(0.059)	(1.192)	(0.088)	(3.008)
ln(Horsepower)	0.041^{**}	0.172	0.033^{*}	0.142	0.048	0.550
	(0.019)	(0.425)	(0.019)	(0.415)	(0.041)	(0.963)
ln(Water Table Depth)	0.002	-0.454	0.019	0.036	-0.038	-2.210^{**}
	(0.021)	(0.504)	(0.030)	(0.421)	(0.025)	(0.883)
ln(Irrigation Time)	0.015	0.254	0.005	0.445	0.018	0.045
	(0.013)	(0.256)	(0.018)	(0.284)	(0.019)	(0.560)
ln(Plot to Well Dist)	0.006	0.296^{***}	0.002	0.301^{***}	0.001	0.203
	(0.006)	(0.074)	(0.007)	(0.081)	(0.013)	(0.210)
Fixed Effects	Upazila	Division	Upazila	Division	Upazila	Division
Observations	728	728	408	408	320	256
Log Likelihood		-216.72		-139.19		-65.79
R^2	0.67		0.79		0.59	

Note: Dependent variable is contract choice, where relational contract = 1 and formal contract = 0. The table reports correlation between the choice of contract and village-level punishment, soil quality, household, and well characteristics. Negative correlation between soil quality and relational contracts is interpreted as evidence in support of Test 1. Negative correlation between severity of punishment and relational contracts is interpreted as evidence in support of Test 2. Columns (1) and (2) present regression results for the entire data set. Columns (3) and (4) present regression results for households living in villages that provide enforcement of formal contracts. Columns (5) and (6) present regression results for households living in villages that do not provide any enforcement. In "No Enforcement" Logit model the Division 5 indicator predict success perfectly and is therefore dropped from the regression. Cluster corrected robust standard errors are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table 6: Average Partial Effects of Contract Choice Equation

	All Buyers (2)	*Enforcement* (4)	*No Enforcement* (6)
Punishment (p)			
Private Punishment	0.092		
	(0.130)		
Economic Punishment	-0.126^{**}	-0.261	
	(0.056)	(0.150)	
Economic Social	-0.251^{***}	-0.398^{***}	
	(0.044)	(0.140)	
Accuracy Signal (k)			
Standard Soil Quality	-0.057^{*}	-0.063	-0.060
	(0.034)	(0.050)	(0.049)
Good Soil Quality	-0.120^{***}	-0.124^{*}	-0.169^{***}
	(0.044)	(0.071)	(0.057)
Household and Well Characteristics			
Discount Rate (0-6 months)	0.072	0.103	0.061
	(0.201)	(0.281)	(0.343)
ln(Wealth Per Capita)	0.043^{**}	0.041	0.070^{***}
	(0.019)	(0.026)	(0.026)
Seller Social Power	0.039^{*}	0.033	0.064^{*}
	(0.022)	(0.032)	(0.035)
Business Partners	0.035	0.038	0.047
	(0.025)	(0.033)	(0.039)
Same Caste/Kin	0.089^{***}	0.130^{***}	-0.025
	(0.029)	(0.032)	(0.044)
Alternative seller	-0.019	-0.029	-0.030
	(0.028)	(0.042)	(0.040)
STW	0.203^{*}	0.221^{*}	-0.620^{*}
	(0.118)	(0.125)	(0.349)
DTW	0.172	0.253^{**}	-0.658^{**}
	(0.110)	(0.126)	(0.321)
ln(Horsepower)	0.016	0.016	0.043
	(0.039)	(0.045)	(0.073)
ln(Water Table Depth)	-0.042	0.004	-0.174^{***}
	(0.047)	(0.046)	(0.060)
ln(Irrigation Time)	0.024	0.049	0.004
	(0.024)	(0.031)	(0.044)
ln(Plot to Well Dist)	0.028^{***}	0.033	0.016
	(0.007)	(0.008)	(0.016)
Observations	728	408	256

Note: The table presents average partial effects for coefficients estimated using the Logit model. See note to Table 5 for details on coefficient interpretation and model estimation. Cluster corrected robust standard errors calculated using the delta-method are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Table 7: Multinomial Logit Estimation Results of Contract Choice Equation

	Village Enforcement		*No Village Enforcement*	
Base: Fixed Charge	Output Share (1)	Two-Part Tariff (2)	Output Share (3)	Two-Part Tariff (4)
Punishment (p)				
Economic Punishment	2.860*	−0.542		
	(1.513)	(0.716)		
Economic Social	4.083***	−0.407		
	(1.521)	(0.607)		
Accuracy Signal (k)				
Standard Soil Quality	0.791*	0.272	1.057	−0.207
	(0.504)	(0.434)	(0.971)	(0.478)
Good Soil Quality	1.221*	0.017	2.262**	0.017
	(0.719)	(0.589)	(1.004)	(0.390)
Household and Well Characteristics				
Discount Rate (0-6 months)	−1.818	−3.896*	0.345	4.364
	(2.842)	(2.000)	(4.400)	(2.856)
ln(Wealth Per Capita)	−0.450*	−0.195*	−1.016***	−0.412**
	(0.273)	(0.158)	(0.303)	(0.194)
Seller Social Power	−0.655*	−0.961***	−0.943**	−0.614**
	(0.350)	(0.278)	(0.459)	(0.302)
Business Partners	−0.502	−0.214	−0.602	−0.001
	(0.322)	(0.261)	(0.540)	(0.321)
Same Caste/Kin	−1.378***	−0.253	0.336	−0.071
	(0.328)	(0.334)	(0.577)	(0.297)
Alternative seller	0.126	−0.246	0.297	−0.305
	(0.385)	(0.329)	(0.489)	(0.394)
STW	−1.087	2.836*	8.652***	1.916*
	(1.063)	(1.506)	(3.280)	(1.017)
DTW	−1.801	0.941	8.750***	0.478
	(1.202)	(1.854)	(2.810)	(1.226)
ln(Horsepower)	0.604	1.021***	−0.231	0.943***
	(0.435)	(0.345)	(0.990)	(0.351)
ln(Water Table Depth)	−0.999**	−1.549***	2.106**	−0.134
	(0.475)	(0.428)	(0.913)	(0.506)
ln(Irrigation Time)	−0.355	0.141	0.217	0.927***
	(0.313)	(0.284)	(0.499)	(0.326)
ln(Plot to Well Dist)	−0.462***	−0.286***	−0.206	−0.049
	(0.102)	(0.103)	(0.211)	(0.103)
Fixed Effects	Division		Division	
Observations	408		320	
Log Likelihood	-269.33		-202.42	

Note: Dependent variable is contract type, with fixed charge as the base outcome. The table reports correlation between the choice of contract and village-level punishment, soil quality, household, and well characteristics. Columns (1) and (2) present regression results for households living in villages that provide enforcement of formal contracts. In villages that provide enforcement, positive correlation between soil quality and output share contracts is interpreted as evidence in support of Test 1. Positive correlation between severity of punishment and output share contracts is interpreted as evidence in support of Test 2. A lack of correlation between soil quality and two-part tariff contracts and a lack of correlation between punishment severity and two-part tariff contracts is interpreted as evidence in support of Test 1 and Test 2 separately. Columns (3) and (4) present regression results for households living in villages that do not provide any enforcement. Although no formal test is examined in columns (3) and (4), we would expect to see positive correlation between soil quality and output share contracts and a lack of correlation between soil quality and two-part tariff contracts. Cluster corrected robust standard errors calculated using the delta-method are reported in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

A Measuring the Principal's Discount Rate

Numerous issues exist in eliciting individual discount 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). 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, our analysis relies only on an ordinal ranking of subjective discount rates. We make no attempt to infer risk preferences or utility from our intertemporal choice data. Despite our limited demands on the data, we have 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 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 months 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. Thus, a 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 that our study simply requires an ordinal ranking of households by discount rate and 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.

Mean interest rates do not vary substantially across time frame or across contract type (see Panel B in Table 2). For our empirical analysis we convert interest rates (i) to discount rates (δ) where $\delta = \frac{1}{1+i}$.