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Water Management Reform and the Choice of Contractual Form in China

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Abstract

This paper explains the puzzling fact that in organizing the management of surface water, village leaders have provided incentives to canal managers in some areas, but not in all. Our study indicates that the optimal contractual choice depends on the relative abilities of the leader and the manager, the design of the cultivated land, the characteristics of the canal system and the opportunity costs of the leader and the pool of managerial candidates. The unifying mechanism is the relative change in the ability of the leader and manager to perform the unmarketable activities that are needed to provide irrigation services.

Keywords: Water management; Irrigation system; Fixed-wage contract; Profit-sharing contract; Fixed-rent contract

JEL Classification: Q25; O17

Summary

This paper explains why irrigation systems are managed differently in different villages in rural China. There are two general types of activities in managing canals: collective activities and supervisory activities. Collective activities include tasks that involve several households such as maintaining canals, coordinating water deliveries and resolving water conflicts. Supervisory activities are tasks that are relatively effort intensive for the leader or manager such as the opening and closing of sluice gates, monitoring water allocations, and collecting water fees. In most villages, the leader is better at organizing collective activities and the pool of canal manage candidates are better at carrying out supervisory activities.

When sorted according to the ways managerial responsibilities and earnings are divided, irrigation systems in China's villages are managed in three distinct ways. In some villages, the leader is in charge of organizing both collective activities and supervisory activities. The leader manages the whole system. He may hire a foreman to help with some tasks under his direct instruction. In contrast, some leaders have transferred complete control and income rights of canals to managers. As long as the manager follows the rules and regulations set by the leader, provides quality irrigation services and pays the contract fee to the village, the leader does not intervene directly in the manager's execution of day-to-day canal management tasks. Finally, in other villages the leader and manager share responsibilities and earnings from the irrigation tasks.

Our study indicates that how the canal in a village is managed depends on the relative abilities of the leader and the manager in carrying out collective activities or supervisory activities, the nature of the cultivated land, the characteristics of the canal system and the opportunity costs of the leader and the pool of managerial candidates. In China, the leader makes these decisions since the canal is a collective asset and he has de facto control rights over the assets. If the leader is also good at organizing supervisory activities in addition to collective activities, he is more likely to choose to manage the canal by himself. If the land in the village is highly fragmented, supervisory activities are more important in managing canals and thus the leader is more likely to choose to rent out the canal to a manager. If the canal is in

good condition and thus less maintenance is required, the leader is more likely to rent out the canal to a manager since collective activities are less important. The wealthier a village is (or the more opportunities there are to find an off-farm job), the more likely it will be that the leader will manage the canal by himself since lower contract fee will be required to induce the manager candidate to run a canal.

Water Management Reform and the Choice of Contractual Form in China

In confronting the inefficient performance of China's irrigation systems, leaders have begun experimenting with new institutional forms to manage water in rural communities. In rural China only 40% of the water that is allocated to irrigation is effectively used, a figure much lower than many developed countries (Wang, 2000). Although the dependence on traditional irrigation technology, such as flood irrigation, accounts for part of the inefficient use of water, poorly designed water management institutions also contribute to the subpar performance (Wang, et al., 2005b). Since the late 1990s, policymakers have promoted surface water management reform, especially in the Yellow River basin. The essence of the reforms is to gradually decentralize management of local irrigation systems by transferring the management of the system from the village leader (the local government, referred to as *the leader* in the rest of the paper) to private managers (typically villagers, referred to as *the manager*).

The record on reforms, however, is mixed, although most evaluations are only based on anecdotes or small case studies (China Irrigation District Association, 2002, Huang, 2001, Nian, 2001). Some observers have reported that the process of water management reform has been successful. At the same time, visits to the field can easily uncover cases in which local water management changes were implemented and subsequently failed. Even in those areas in which management reform has been well-designed, effective implementation of the reform has been difficult (Ma, 2001, Management Authority of Shaoshan Irrigation District, 2002).

Unlike most anecdote-based research, Wang et al. (Wang, et al., 2005b)study a set of randomly selected villages in the Yellow River Basin and find that the success of water management reform in China is positively correlated with the incentives that are provided to managers. In the study area, leaders provide incentives to managers by offering them shares of the profit from the operation of the village's irrigation system. In some villages the canal networks are leased to individuals for a fixed contract fee and the individuals keep all of the earnings net of expenses; in other villages the managers of the water management committee are rewarded with part of the water fees that are collected after the irrigation network's expenses have been paid. In villages that provide managers with strong incentives to save water, water use falls sharply while having almost no effect on agricultural production or rural incomes. In contrast, when villages do not provide incentives, managers do not save water.

One question Wang et al. (2005b) do not answer, however, is that if incentives work so well, why is it that all villages do not provide incentives to their managers. To try to explain this puzzling fact, the overall goal of our paper is to provide a framework for explaining the choice of managerial form. To meet the overall goal, we have two specific objectives. First, we set up a theoretical framework that predicts how the contractual form varies with the nature of village's cultivated land, the design of the canal system and the characteristics of its leaders and the pool of managerial candidates. By candidates, we mean individuals within the village that are eligible to take on the role of a canal manager. Since any villager is eligible, the pool of managerial candidates refers to all the villagers in our sample villages. Second, we seek to empirically identify the factors that may induce leaders to choose one type of contractual form over another by using descriptive statistics and multivariate analysis.

The novelty of this paper is that we treat the managerial form of China's most basic management unit of the village's irrigation system as endogenous and econometrically measure the factors that determine how water is managed. Unlike most previous studies that are anecdote-based, we use the data that we collected from 32 villages and 40 canal village-level systems in northern China to describe and econometrically identify the determinants of the managerial form. This is the first empirical village-level study on this subject in China. More importantly, we have incorporated important factors that were not analyzed in previous studies: the characteristics of the key players. In most past studies, discussions of the appropriate institutional forms are usually limited to overcoming the transaction costs of enactment (Easter, et al., 1998) or the legal and physical restrictions to their establishment (Radosevich, 1988). Baland and Platteau (1999, 1997) are among the few other authors (Dayton-Johnson, 2000a, Dayton-Johnson, 2000b, Fujiie, et al., 2005) that discuss the impact of local characteristics on the success of proposed institutional arrangements for managing the commons, although none have examined the characteristics of the key players. In our study we examine the role the leader and the pool of managerial candidates play in the endogenous choice of managerial forms.

The rest of this paper is organized as follows. We first summarize the existing contractual forms. In the next section we model contractual choices formally and, based upon the results of the simulation analysis, make four predictions about the factors that determine how contractual relationships are formed in different types of environments. During the discussion, we also relax some assumptions and modify the predictions. Using the predictions as a basis for generating testable hypotheses, our empirical work analyzes the relationship between contractual choice and a number of different characteristics of a village: the nature of its cultivated land, the design of its canal system and the characteristics of the leader and the pool of managerial candidates. In the final section, we conclude.

Three Forms of Contracts in Managing the Canal System

The managerial contract between the leader and a manager governs not only each party's responsibilities in the operation of canals, but also their rights to claim the residual profits from irrigation services. There are two main types of activities in managing the canal system: *collective activities* and *supervisory activities*. Collective activities include tasks such as maintaining canals, coordinating water deliveries, and resolving water conflicts that involve several households. Collective tasks typically require the leader or manager to coordinate or facilitate negotiations among villagers. It should be noted, that collective activities in our paper are distinctly different from the term *collective action* in Ostrom (1990). In our case the leader or manager organizes the actions of villagers in the execution of a set of water management tasks; in Ostrom (1990) villagers must find ways to cooperate among themselves, often in a self-organizing way. In contrast, supervisory activities are tasks that are relatively effort intensive for the leader or manager. In the operation of a canal system many supervisory tasks, such as water delivery (e.g., the opening and closing of sluice gates), monitoring water allocations, and collecting water fees, are the key elements in the system's efficient and profitable operation. One of the fundamental ways that canal systems vary is that in some communities the leader assumes responsibility for all of the tasks; in other villages the manager assumes responsibility for most of the tasks; and in others leaders and managers share responsibilities. Not surprisingly, in return for taking on greater (or fewer) responsibilities for implementing the different tasks, leaders and managers are compensated with more (or less) of the earnings of the system.

When sorted according to the ways managerial responsibilities and earnings are divided, irrigation systems in China's villages are managed in three distinct ways. Some villages have chosen to stay with the traditional form of leader-run irrigation management. In these villages, the leader is in charge of organizing both collective activities and supervisory activities. The leader either manages the whole system by himself, as part of his regular duties, or hires a foreman for a fixed wage to perform some of the water management tasks under his direct instruction. Importantly, under such a *fixed-wage* contract (assuming the leader even decides to hire a foreman – or more precisely a fixed wage worker), the foreman does not have a strong incentive to put out effort since he does not get any share of the profit from the operation of the irrigation system. In fact, because the leader knows this, the foreman is not really expected to take much initiative and at most carries out fairly routine activities under the direction of the leader.

In contrast, some leaders have transferred complete control and income rights of the village's canal network to managers on the basis of a *fixed-rent* contract. Under such an arrangement, the individual has effectively become the manager of a private water management company and is provided with full incentives. As long as the manager follows the rules and regulations set by the leader, provides quality irrigation services and pays the fixed rent (or in terms of China's villages, the contract fee), the leader does not intervene directly in the manager's execution of day-to-day canal management tasks, neither collective activities nor supervisory ones. Finally, in other villages the leader and manager share both responsibilities and earnings from the irrigation tasks, a form of management that is called a *profit-sharing* arrangement. To *maximize the profit* from operating the village's irrigation system (or at least to operate it efficiently), one of the key decisions the leader needs to make is to put the individual that can run the irrigation system most efficiently in charge and to provide that individual with the incentives to do so. In other words, the leader decides how his village's irrigation system is managed by choosing the contract that will return the highest level of profits. Thus, the profit-maximization behavior of the leader is consistent with efficiency from a social perspective.

Modeling Managerial Choice in Rural China

Since ultimate property rights reside with the leader as the curator of local assets in rural China, the leader will choose the contractual form that will further his interests. After the onset of the rural financial reforms, leaders have been encouraged to use village assets efficiently and are allowed to run them, where appropriate, on a fee for service basis (Oi, 1999, Rozelle, 1994, Whiting, 2001). Description of policies and regulations that promote the efficient use of irrigation system—both groundwater and surface water—are found in Lohmar et al. (2003) and Wang et al. (2005a). Importantly, these policies implicitly allow the leader to claim profits from such service-oriented activities (e.g., the water fee collected in the case of running irrigation systems) as the reward for building the village's treasury (Rozelle, 1994).[1] As a consequence, we believe that it is not unreasonable to assume that the leader's interests frequently are consistent with profit-maximization (Oi, 1999).[2] In this section, we take on the challenge of developing a way to understand how different communities in China choose to manage their irrigation systems—as fixed-wage, fixed-rent or profit-sharing contracts.

Two basic assumptions

Following Eswaran and Kotwal (1985), we outline a theory to explain the different ways in which villages manage their irrigation systems.[3] In developing a model in which the leader endogenously chooses the optimal contractual form, we make two basic assumptions. First, the leader and the manager

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[1] This situation is different from that described in Platteau and Gaspart (2003) in which the funding is entrusted to the leader ("the elite members" in the paper) by non-governmental organizations for the purpose of community development but is often used by the leader for his personal benefit.

[2] While we also study the conditions under which a certain type of resource managerial form arises, our paper differs from the common property resource community management literature. Instead of examining the choices of users that self-organize for the purpose of resource management, in our case the leader is solving an optimization problem in order to decide how to manage the community's irrigation system. Like the water users in Ostrom (1990) who are searching for the institutional arrangement that minimizes transaction costs and internalizes externalities, the leader considers the characteristics of the environment and chooses a managerial form that maximizes the return to the irrigation assets. Such behavior is entirely consistent with the way in which China has implemented its reform era policies (Park and Rozelle, 1998).

[3] The word *outline* is used since the authors borrow heavily from Eswaran and Kotwal's (1985) model of contractual choice in tenancy contracting. The authors take credit, not for producing a new analytical framework, but rather for applying an existing theory to a different question.

have an absolute advantage in being able to perform one or the other of the two activities that are required to run an irrigation system. As the local authority, the leader is efficient at organizing collective activities such as mobilizing the labor of his villagers to clean canals, coordinating irrigation schedules among households and resolving water conflicts. For example, using his executive authority, the leader can easily (at least in relative terms compared to any individual villager) mobilize households within the village to clean and perform maintenance work on the village's canal system on a seasonal or annual basis. If an individual manager were in charge of maintaining the canals on his own, he would almost invariably have to hire labors from inside and/or outside of the village to help him do so.

In contrast, we assume that the manager is endowed with a superior ability (and more available time) to execute supervisory operations. For example, while there is no reason to believe that leaders could not effectively manage water allocation operations if they had the time, one of our key points is that they often do not. Since the leader is also invariably burdened with many other duties, such as running village enterprises, implementing family planning, maintaining local schools and health facilities, as well as a myriad of other administrative responsibilities assigned by township officials, he almost assuredly is less able to provide the concentrated effort and attention to detail that is needed in certain villages to allocate water and provide other irrigation services. A full time manager, however, can focus his energy and often can draw on his family members to provide the hours needed to meet the irrigation needs of the farmers in the command area. In addition, managers sometimes have an advantage over leaders in the time-intensive job of collecting water fees. Besides being a time-consuming task (almost always requiring going door-to-door, sometimes many times), households often will use various excuses to avoid or delay payment to the leader or his foreman, frequently taking advantage of the fact that the village is at least partly considered responsible for providing welfare functions to needy villagers. The leader may also be worried that if he forces the villager to pay the water fee, the villager will vote against him during the next election. These tactics are less effective when managers, who themselves are fellow-villagers, come to collect payment for services rendered.

Our second key assumption is that the abilities of the parties to organize collective activities and supervisory activities are unmarketable, partly because those services are unobservable and therefore difficult to measure. For example, the leader could hire an individual foreman to supervise water delivery. In theory, the leader would like to pay a wage to the foreman on the basis of the amount of effective work that he does. However, it is difficult for the leader to monitor the foreman, and it is impossible to measure the amount of effective work even after the tasks are performed. As a consequence, it is difficult for the leader to provide an incentive for the foremen. For these reasons, it is difficult or impossible to purchase the effort that is needed to execute supervisory tasks on the market. To obtain effective supervisory activities, the leader either has to do them himself or provide self-monitoring incentives to an individual that is able to carry out this task. Likewise, a manager cannot procure the authority that is needed to execute collective activities on the market.

Model

In most surface water irrigation areas in rural China, the distribution of water is organized at two levels: at the first level, the irrigation district (ID) is responsible for supplying water to irrigation units, which in China is almost always an administrative village; at the second level, the village committee (which is the governing body at the lowest level of quasi-government in rural China). In our problem, the village committee decides to manage the village's water resources itself (traditional collective management) or contracts the canal system out to a manager (a profit-sharing contract or a fixed-rent contract), and it is this management unit that is responsible for delivering water directly into the fields of farmers. When water passes from the ID to the village (that is at the first level), irrigation water is typically priced volumetrically because the volume of water can be measured fairly accurately as water passes out of the main, ID-controlled canal network into the village-controlled branch canal system. When purchasing water from the ID, the village committee (or the manager) usually pays a deposit to the ID before the irrigation season (as a down payment for the water to be used during the year); after the water is delivered to the village, the village committee (or the manager) needs to pay the balance.

Within the village, however, the situation is often fundamentally different. At this level, the household is obligated to pay a fixed water fee for irrigation services during an irrigation season or a year. Although the village leader or the manager would like to charge on a volumetric basis, due to the difficulty of measuring water at the plot level, the household's water fees are often converted to a per unit of land basis. Although there is heterogeneity across IDs and even villages within the same ID, in most villages the water fee (which is fixed in terms of yuan per unit of irrigated land) was determined by the ID or the bureau that manages the ID (about 65 percent of the villages). In other villages (20 percent or so) the village committee set the household's water fee. In the rest of the villages—especially in those village that contract out their canal network to a manager for a fixed-rent or profit-sharing contract, the water fee was determined together by the village leader and the canal manager (15 percent of all the villages). Importantly, in all of our sample villages, there was no difference in level of water charges among households within the same village; in fact, there was only a small degree of variation in the water fee between different irrigation seasons within the same year (summer/early cropping season; and fall/late cropping season).

Hence, managing a canal in the village is similar to running a water company. The leader or the manager purchases water as an input from the ID and provides irrigation services to households. Output, in this case irrigation services (Q), generally includes the water that is delivered to the fields of farmers at the times and in the quantities that are needed. In other words, the product being provided to the farmers by the irrigation system is far more than a volume of water; it is the entire package of services, including the timing, frequency as well as the quantity of water delivered. Hence in our study, we measure Q as revenues from managing the community's canal system.[4] Since, as discussed above, in villages that use

[4] In theory, output should be in units of "irrigation services." Unfortunately, like most service sector firms, the output is difficult to measure in physical terms. Our use of revenue is reasonable under the assumption that irrigation service revenue in some sense is an aggregate measure of individual services (irrigation timing; frequency and quantity) that have been implicitly weighted by the prices of each service, the summation of which is the total revenue of the irrigation system. In our problem, this is measured as the sum of irrigation fees paid by all the households in the village. Such a strategy is common in the production economic literature when a firm is producing a number of varied products. For example, in estimating a household-level cropping production function of a farmer that produces a mix of grain and cash crops, it is common practice to add up the revenue of the farm's output and use total revenue as the dependent variable. Such a measure is still considered to be physical output: the prices are used as weights to aggregate across outputs that are measured in different physical units. Hence, in the

surface water households pay a fixed amount of fee for each unit of irrigated land they have, the output, *Q*, is thus calculated as the total amount of fees collected from all the households within the village. The more irrigation services the leader/manager provides, and the less water they use, ceteris paribus, the higher is the profit.

Since the irrigation services are not just the volume of water delivered, other inputs besides water are also required in the provision of irrigation services. One such input is the quality of the system's *infrastructure* (*H,* measured as the length of the canal that is lined). Most importantly, the right hand side of the production function also includes the two key inputs, time spent in providing collective activities (*t*, measured as the number of days spent by the manager in organizing the maintenance of the canal system, mitigating conflicts over water, etc.) and effort spent on operating the system.[5] Effort, however, consists of two parts: the manual labor (*L*) required in running the irrigation system; and time spent on supervision (*s*) to monitor the labor and supervise the operation of the system (e.g., operating sluice gates and collecting water fees). Both *L* and *s* are measured in days. The production function's parameters (δ_1 to δ_5) embody information about the irrigation system's technology, which will reflect the relative importance of the key inputs.[6] Given these variables, we can relate the inputs to irrigation services using a Cobb-Douglas production function:

$$Q = \theta A t^{\delta_1} s^{\delta_2} L^{\delta_3} W^{\delta_4} H^{\delta_5} \text{; and} \qquad A > 0, \quad \delta_i > 0, i = 1, 2, 3, 4, 5. \qquad (1)$$

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same way that it is not correct to add the output of grain and cotton in physical terms, it is not correct to measure the output of the irrigation system in terms of the physical delivery of water (in cubic meters).

[5] In the questionnaire, we had a section that collected information on the time spent on collective and supervisory activities in managing canals. In this section we created a disaggregated list of the activities that most leaders and/or managers had to perform (e.g., operation of sluice gates, canal maintenance, water fee collection, mitigation of water conflicts and other administrative responsibilities). This list formed the basis for the block of the survey in the questionnaire that elicited time allocation of the leader/manager; we also left room for additional activities. For each activity, we asked who carried out these activities (the leader or the manager), whether they hired labor (or had their relatives/family members helped them—that is, hire for a zero wage) and how much the hired labor was paid. We asked these questions on a month by month basis for all 12 months of the survey year 2001. In our analysis, the value of *t* (*s*) is calculated as the total amount of time spent on collective (supervisory) activities throughout year 2001. During the interviews, we asked the interviewees to convert the time into labor days using the criterion that one labor day was equal to 10 working hours. The descriptive statistics on *t* and *s* are in Appendix B.

[6] We also believe that the inputs in providing irrigation services are more likely to be substitutes for each other. For example, when the price of water is higher, the village leader or the canal manager will use less water (*W* is lower). In addition, the leader or the canal manager will spend more time on supervisory activities to monitor more closely the opening and closing of the gates so that a higher percentage of the water purchased from the irrigation district is delivered to the field.

where θ is a positive random variable with an expected value of unity, intended to embody the effects of such stochastic factors as weather. For example, when there is abundant rainfall, irrigation services would be easily provided. On the other hand, in a dry season, water delivery is a difficult task. For the sake of brevity, in the theoretical model, we assume the leader and the canal manager are risk-neutral and thus the effect of the random variable, θ, is not discussed. In later sections, we relax the assumption of risk-neutrality and discuss the possible impacts of the risk attitude of either the leader or the manager on the contractual choice in a village.

The leader of each village considers the production function of irrigation services (equation 1), the characteristics of his village, his own characteristics and the characteristics of the pool of potential managers and solves three different *problems* for himself: how much profit would I make if I ran the irrigation system myself (as a fixed-wage contract); how much rent would I make if I leased it out (as a fixed-rent contract), and how much profits would be left for me if I split the duties and profits with a manager (under a profit-sharing agreement). He will then choose the contractual form that returns to him the highest level of profit.

In choosing the optimal contract, the leader must be able to provide the right level of incentives to the manager to operate the irrigation system—given its characteristics—most efficiently. To allow our model to reflect these decision-making criteria, we need to quantify the assumption that the leader has an absolute advantage in organizing collective activities and that the manager has an absolute advantage in carrying out supervisory activities. Hence, we define the time a leader spends on collective activities (supervisory activities) as t_1 (s_1—where 1 refers to the leader for the rest of the paper) and define the time a manager spends on collective activities (supervisory activities) as t_2 (s_2—where 2 is denotes the manager). The idea of differential ability is quantified by the introduction of two parameters, γ_1 and γ_2. It is assumed that one hour of the leader's (manager's) time devoted to supervisory activities (collective activities) is equivalent to only a γ_1 (γ_2) fraction of one hour devoted to supervisory activities (collective activities) by the manager (leader). Both parameters, γ_1 and γ_2 are between 0 and 1.

Defined in this way, the benefit of choosing a fixed-rent contract when an irrigation system requires relatively more tasks that are supervision-intensive is clear. The leader gives full incentives (that is, the manager becomes the residual claimant of profits after paying the contract fee) to the manager since the leader wants the manager to fully utilize the manager's own *efficient* supervisory skills. Unfortunately, the provision of incentives to the manager can only come at a cost; the manager also will be providing the collective activities, which he can do, but only inefficiently. Following this logic, it is easy to see why in other irrigation systems, for example those that require relatively more input of collective activities, the leader will decide to run the irrigation system himself and keep the profits, fully utilizing his skills in providing collective activities, albeit at the cost of less effective delivery of supervisory activity. Details of the model are found in Appendix A.

Operationalising the model

In creating a simulation model of the village's irrigation system that will allow us to study contractual choice, we use data (discussed below) to estimate the function coefficients (δ_1 to δ_5) of the irrigation services production function in equation 1. In estimating equation 1, we need to address a number of econometric issues. The production function is estimated with and without fixed effects at the level of the ID (as well as using an alternative set of regressions in which we use fixed effects at the county level). Using a fixed effects model allows us to account for unobservable differences in local characteristics that might affect the provision of irrigation services such as the level of precipitation. When a fixed effects model is used, the fixed effects also capture the effect of observable characteristics such as the local topography. For example, it is much easier to deliver water in plain areas than in areas with sloped land. We also recognize that our measures of *t*, time spent on managing collective activities, and *s*, time spent on carrying out supervisory activities, are measured with error. We assume that the time spent by the leader (manager) on supervisory (collective) activities is systematically less efficient than that of the manager (the leader). However, we could only collect data on the actual time they spent on these activities. In addition, the leader and the managers might have some incentive to over-report the time they spent on the activities they are responsible for. With these measurement errors, there will be an attenuation bias in the estimated coefficients that measure the relationship between irrigation services and supervisory time (time spent managing collective activities). Although we have no way to correct for this (since we lack any valid instrument), in our simulations (presented below) we recognize the direction of the bias and use sensitivity analysis to show that our hypotheses (that use the parameters for simulation) are robust to the biased coefficients.

Using our data, the estimation of irrigation production function performs well (Table 1). Our data failed to reject the assumption that the production technology is characterized by constant returns to scale (CRS). The estimated function coefficients, d_1 to d_5, do not differ statistically between the model with and without fixed ID or county effects. The R^2 is relatively high for all of the estimated production functions. Each of the input variables also has the expected positive signs. We ultimately use the estimated coefficients from the model using fixed effects at the county level in our simulation analysis (Table 1, column 3).[7]

Using our estimates, we are able to parameterize our model in Appendix A with parameters that are consistent with our data. For example, our baseline parameters for the production coefficients are: $A = 3264.95$, $d_1 = 0.015$, $d_2 = 0.174$, $d_3 = 0.043$, $d_4 = 0.725$, and $d_5 = 0.043$.[8] We also set the opportunity cost parameters of the leaders and managers, v=1 and u=0.8, so that they are consistent with what we observe in the field; in our data the average daily wage of leaders exceeds that of managers by about 20 percent.

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[7] Note that the estimated coefficient on the variable t is not significant. One explanation is that this is due to the attenuation bias caused by the measurement error associated with t. Unfortunately, we have no way to correct for this since we do not have any valid instrument. However, in the simulations t is still used because we believe that collective activities are essential in providing irrigation services. During our pre-test, we asked the village leader and/or the canal manager to list all the major activities they have carried out in managing canals. Unanimously, collective activities such as cleaning canals and maintaining the canals were on the list for all the leaders and managers we interviewed. We were also told that when the village leader decided to offer a profit-sharing contract or a fixed-rent contract, one of the most important terms in the contract was to define the responsibilities of the leader and the manager regarding the collective activities. Hence there is no doubt that collective activities are important in providing irrigation services and will definitely affect the contractual choice of the leaders. In our simulations we recognize the direction of the bias and use sensitivity analysis to show that our hypotheses are robust to the biased coefficients.

[8] Since water is not priced volumetrically within the village, the revenue from providing irrigation services, which is calculated as the sum of water fees by all the households in the villages, is not perfectly correlated with the volume of irrigation water used in the village. However, since the water fee per unit of land is usually determined based upon an estimated average amount of water applied in irrigation (and a certain amount of service in some villages), the water fee is correlated with the volume of water. The degree of correlation depends on how close is the water use of one household to the average level. This may be part of the reason that the coefficient on the water input is closer to one than those of other inputs.

We also set the level of the input prices, *w*=0.8, *r*=0.004, on the basis of our data; in our sample, water price per cubic meter (*r*) is around 0.5 percent of the observed daily wage (*w*).[9] Sensitivity analysis is performed throughout the analysis to ensure our choices of parameters are not driving the results.

Figure 1 illustrates the partitioning of the contract space based upon the relative efficiency parameters, γ_1 and γ_2. In figure 1, γ_1^c and γ_2^c are the critical values of γ_1 and γ_2: the point at which the leader will choose to switch from a profit-sharing to a fixed-wage contract, or the point at which he would switch from a profit-sharing to fixed-rent contract. The values of γ_1^c and γ_2^c can be used to partition the contract space into those areas where fixed-wage, profit-sharing and individual contracts are optimal. In the figure, we keep the values of the other parameters (*A* and $\bullet_1$ to $\bullet_5$) constant. The only thing that varies is the relative efficiency of the leader's (manager's) ability to perform supervisory (collective) activities. The determination of the critical values can be found by simulating the model (solving the three problems of leader—fixed-wage; fixed-rent; and profit-sharing—and comparing the profit levels of each to find which generates the highest expected income) across a grid of γ_1 and γ_2 values (varying each from 0 to 1 by increments of 0.01). The result of such an exercise is denoted by the solid lines in Figure 1. If a characteristic of the village's irrigation system or the actors were changed, it is possible that γ_1^c and γ_2^c would change. [10]

Predictions

The basic results from Figure 1 can be used to gain some intuition about why the form of the contract between the leader and a manager varies across space. The relative efficiency of the leader (manager) to perform supervisory (collective) activities, $\gamma_1(\gamma_2)$, differs from village to village. If besides having a superior ability to organize collective activities, such as canal maintenance, a leader also is willing and able to devote himself to supervisory activities, such as water allocation and fee collection,

[9] The wage for labor is about 20 yuan/day. The water price paid to the ID is around 0.1 yuan/m^3 in many villages.
[10] Because it is possible that the values of δ_1 and δ_2 are underestimated (see discussion above), we repeated the simulations that underlie Figure 1 for a variety of different parameterizations of δ_1 and δ_2. Although the size of the area for profit-sharing (and the other contractual arrangements change), the general configuration stayed the same; the same is true for other comparative static simulations using the results from Figure 1.

(that is the leader has a relatively high value of g_1), the leader may choose to manage the village's canals by himself and at most only hire a foreman at a fixed wage to carry out certain routine irrigation tasks under his instruction. If on the other hand, a manager's ability to organize collective activities, g_2, is high, the leader may prefer to lease out the canal to an individual manager for a fixed-rent contract. When the leader (manager) has little hope of increasing his ability to carry out supervisory (organize collective) activities and the values of g_1 and g_2 are both low, the leader may choose a profit-sharing arrangement whereby both the leader and manager share in the duties and also share the system's earnings.

From figure 1, then, we can make the first prediction of the model:

<u>Prediction 1:</u> *The dominant contractual form in a given village depends on the relative ability of the villager leader (manager) to perform supervisory (collective) activities. The more experienced the leader (manager) is at supervisory (organizing collective) activities, the more prevalent will be fixed-wage (fixed-rent) contracts.*

Even if the ability of the leader (manager) to perform supervisory (collective) activities is constant (that is, g_1 and g_2 are constant), changes in other factors might lead to changes in g_1^c and g_2^c. Examining the associations between contractual choices and the other factors also will help explain differences among villages in their choices of irrigation system management. Panels A to C in Figure 2 illustrate the results of three comparative static exercises.

According to the first exercise, the optimal managerial form depends on the nature of the village's cultivated land that can determine the relative importance of supervisory activities and collective activities (Figure 2, Panel A). For example, in villages with canal systems that wind intricately through fields of highly fragmented plots that are spread out spatially, the water delivery task is more demanding in that each household may grow different crops on different plots that have different water delivery quantity and timing requirements. Additional efforts are also needed towards the collection of water fees.

In such a setting, there is a greater need for the manager to take on supervisory activities. Therefore, a leader will be more likely to offer a fixed-rent contract to a managerial candidate who can more efficiently deliver water and meet the specific water delivery requirements of each household (Figure 2, Panel A). In the notation of our model, when supervisory activities are highly valued, the value of the parameter d_2 increases, and we can summarize with a second prediction:

<u>Prediction 2:</u> *The optimal contractual form in a village depends on the nature of its cultivated land, such as the degree of land fragmentation. As land becomes more fragmented, supervisory activities become more valuable and the leader will be more likely to grant a fixed-rent contract to an individual manager.*

Given the nature of village's cultivated land (and relative strengths of leaders and managers), the characteristics of the canal system also can determine the relative importance of the two activities. For example, lined canals typically require less maintenance (or are less *maintenance intensive*). In such a case, collective activities are less important. As a result, we might observe that d_1 (the importance of collective activities in producing irrigation services) decreases relative to d_2 (the important of supervisory activities). Since the leader will not play a role in managing the day-to-day operation of canals, there is a relatively greater need for a motivated manager to operate the rest of the irrigation system. Under these circumstances, there should be a greater propensity for the profit-maximizing leader to move away from a fixed-wage contract into a fixed-rent contract (Figure 2, Panel B). Thus, we can make a third prediction:

<u>Prediction 3:</u> *The optimal contractual form in a village depends on the design of the canal system that determines the degree to which the canal system is maintenance intensive. The less maintenance intensive is the canal system, the less important are collective activities, and the more likely it is that the leader will select a fixed-rent contract.*

Finally, our model can show that, holding other factors constant, if the opportunity to find an off-farm job is high for the pool of individuals that potentially could take on the role of manager, the opportunity cost (u) of forgoing other jobs to take on the tasks of managing the village's canals will increase (Figure 2, Panel C).[11] In this case g_1^c will decrease (or g_2^c will increase) relative to that of a village in which it is more difficult for managerial candidates to find other jobs. The change in the relative values of the opportunity cost parameter of the managerial candidate versus the leader will change the bargaining power of the managerial candidate; as *u* rises, the leader will have to lower the fixed rent or increase the share (required by the managerial candidate) to attract the managerial candidate to take a fixed-rent or profit-sharing contract. As a result, under such circumstances, it would be less profitable for a leader to offer a fixed-rent or profit-sharing contract, and we can summarize this as follows:

> <u>*Prediction 4:*</u> *The optimal contractual form in a village depends on the opportunity cost of the leader and the pool of managerial candidates, which is associated with the social-economic environment of the village. The wealthier a village is (or the more opportunities there are to find an off-farm job), the more likely it will be that a fixed-wage contract is chosen.*

To summarize the results of our model, a number of factors affect the optimal choice of contract in rural China: the relative abilities of the leader and the manager, the nature of the cultivated land, the design of the canal system and the opportunity costs of the leader and the pool of managerial candidates. The unifying mechanism driving this evolution, in all cases, is the relative change in the ability of the leader and manager to perform the unmarketable activities that are needed to provide irrigation services.[12]

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[11] In this paper, we assume higher opportunities to find an off-farm job for villagers do not change the opportunity cost of the leader (at least during his current term). When becoming a leader, the individual commits himself to fulfilling a large set of duties that include tasks such as implementing family planning, managing the village's land and adjudicating disputes among villagers. Burdened with these many duties, the leader almost never has time to spend intensively participating in an off-farm job during his tenure. In many places, rules prohibit him from physically leaving the village to take an off-farm job outside the village.

[12] Baland and Platteau (1999, 1997) among several other papers also consider the effect of inequality on the willingness of participants to cooperate in the management of the commons. Since we do not have the level of inequality in land-holdings in rural China that are seen in other settings, where this type of issue might play a big part in how farmers interact with each other (e.g. India and Mexico), we have decided to focus on other determinants that we feel are more critical to the type of institutions that are formed in managing local water resources.

Relaxing the assumptions and modified predictions

Although the predictions derived from the theoretical model are quite intuitive, some modifications may be needed when we examine how these predictions play out in the real world. One important simplifying assumption used in the above sub-sections is that both the leader and the manager are risk-neutral. In an environment with uncertainty (reflected by the parameter, q, in equation 1), whether the leader and/or the manager are risk-neutral will affect the contractual choices. As is well known in the share contracting literature, with production uncertainty, the choice of contractual form affects not only the share of the responsibilities and the residual profit, but also the sharing of risk between the leader and the manager (Otsuka, et al., 1992). Under a fixed-wage contract, the leader is burdened with all the risk. In contrast, the manager shoulders all the risk under a fixed-rent contract. The leader and the manager share the risk under a profit-sharing contract. If in reality leaders and managers are risk-averse instead of being risk-neutral, we may observe some patterns that are not predicted by our basic theory, which is based only upon each agent's absolute advantage in supplying management inputs. For example, if the leader is risk-averse, he may prefer a profit-sharing contract to a fixed-wage contract even if other factors (e.g. the design of the canal system) allow for higher profits if he manages the canal system himself. Similarly, if the manager is risk-averse, he may be reluctant to take a fixed-rent contract. Hence, when the leader and/or the manager is risk-averse, the village's canal system may be run under a profit-sharing contract even if Prediction 1 to 4 point to a fixed-wage or fixed-rent contract. In the rest of our analysis, we shall call this the *risk effect*.

Although the motivation to share risk could make a profit-sharing contract preferable to other types of contracts, situations exist in which the desirability of a profit-sharing is reduced. Under a profit-sharing contract, since the manager and the leader can only claim a fraction of the residual profits, they have weaker incentives. Given costly monitoring in our theoretical framework, it is possible that the manager will shirk and a moral hazard problem could arise (Marshall, 1956, Otsuka, et al., 1992). Since the manager may not commit to provide the optimal effort level and the enforcement of his effort is unlikely, the irrigation services provided under a profit-sharing contract may not meet the minimum amount required by the villagers. The inefficiencies that could arise under a profit-sharing contract may reduce the tendency of leaders, who have responsibility to provide at least the minimum irrigation requirement in the village, to choose to use a profit-sharing arrangement. If so, we might observe profit-sharing contracts only in those areas in which the impetus for profit-sharing is coming from some other motive rather than from the desire for the leader to specialize in canal maintenance and the manager to specialize in supervision (e.g., the impetus to share the risk). In the rest of this analysis we will call this an *absence of an ability to commit effect*.

While predictions 1-4 and the following modifications are intuitively appealing, in the next section, we first use descriptive statistics to see whether the types of contracts vary systematically with the factors predicted in the theory. We then test the predictions empirically with more rigorous multivariate analysis. Such analysis will help us meet our second objective of identifying what factors have caused some villages to implement water management reform and what factors have kept other villages from doing so.

Data

The data for our study come from a survey that we conducted in 32 randomly chosen villages within two IDs in Ningxia, a province that is located in the upper reaches of the Yellow River Basin. The survey was conducted in January 2002. Within Ningxia province we chose one ID in the upper reaches of the river basin and one in the lower reaches. Within the larger ID (Qingtongxia), which is comprised of nine counties, we chose one county from the upper, middle and lower sections of the ID. In the smaller ID (Weining), we included both of the counties that make up the majority of the district's command area. From within each county we randomly selected two townships, from which we randomly chose two villages to include in our sample. In total, we surveyed 32 villages in Ningxia province, and administered a community-level questionnaire to the leader and a separate questionnaire to each village's canal manager, if there was one.[13]

In our interviews and formal surveys with leaders and individual managers within each sample village, enumerators asked detailed information on the canal's contractual form and management activities in year 2001. In particular, we asked the leaders and managers to list the activities that they were responsible for and the hours spent performing such activities (for example, activities such as cleaning canals, opening and closing sluice gates and collecting water fees). Leaders and managers also reported the way in which they were compensated. For example, we asked for each actor's share of the profits from the operation of the irrigation system. In order to classify a contract as fixed-wage, we include villages in which there was no one except the village leaders involved in canal management (6% of fixed-wage contracts) and villages in which the foreman (or person—who is not a cadre—responsible for the operation of the canal system) is paid either a truly fixed-wage—88%—or is paid a salary that is less than 10% of the profits of the irrigation system—6%. A contract is categorized as a fixed-rent contract if the manager is the full residual claimant of the earnings of the irrigation system (i.e., his share is 100% and the village only receives a lump-sum fee that is paid before beginning of the agricultural season). The remainder of the canal systems is categorized as profit-sharing contracts.

The manager survey collected information on a wide number of other variables that we use to explain the determinants of contractual choice.[14] To measure the nature of the cultivated area within which the canal system is operated (which in theory should also affect the relative importance of collective and supervisory activities), we included questions that led to the creation of two variables. The *degree of fragmentation* is measured as the average number of plots of each household in the village.[15]

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[13] There are 8 villages in our sample (32 villages) that have two canals. So in total we have 40 observations.

[14] For many of our variables, we collected information from both the manager (in the manager form) and the leader (in the leader form). For technical information about the characteristics of the canals and the conditions of the agronomic environment, we relied on the manager form. While in the village doing the survey, however, enumerators made an effort to reconcile the answers of the leaders and managers, so in general, information from both forms were consistent. Information on characteristics of the village's socio-economic status (e.g., per capita income; share of non farm income in total income; share of migrants in the village's labor force) came from the leader questionnaire.

[15] In our survey, a plot is primarily defined as a piece of cultivated land of a farm household that is physically separate from all other cultivated land of the household. In some cases, however, a farmer will cultivate two or more different types of crops on a

Water abundance is measured as an indicator variable that takes the values of 1, 2, 3 or 4. Water abundance is equal to 1 when a village's water resources are considered (by the village leader's subjective evaluation) to be highly scarce and equal to 4 when its water resources are considered to be abundant.

We also created three variables to measure the design of the village's canal infrastructure: *canal lining* (measured as lined if at least 10 percent of the length of the canal system within the village is lined); the *propensity to silt up* (which is a dummy variable that is equal to 1 if the respondent answered yes to both of the following questions: Does your canal system ever silt up? Is the siltation considered to be serious?); and the *density of sluice gates* (measured on a per kilometer basis as the number of openings in the irrigation system that were designed to move water from the irrigation canal network into the fields of farmers). These three variables, associated with the physical design of the village's canal, are included to measure the relative importance of collective and supervisory activities in each village's irrigation system.

To capture the opportunity cost of the pool of managerial candidates, we construct two variables from the leader questionnaire that asked about the socio-economic status of the community in detail for years 1990, 1995 and 2001. The opportunity cost of the pool of managerial candidates is captured in part by the *share of off-farm income*. This is measured as the average share of off-farm income in total household income. Alternatively, we measure the opportunity cost of the households in the village as the *proportion of migrants* (measured as the percentage of the village's labor force that lives and works outside of the village for at least one month per year). Both variables were measured during 1995 in order to make them exogenous.

Finally, we use standard measures of human capital, education and age, as proxies for the ability of leaders and managers to organize collective activities or take on supervisory activities. The *level of education of the leader* is measured as the number of years of education actually attained by the leader. Better educated leaders may be better suited to run supervisory activities versus those with poorer education. The *age of the leader* captures the level of physical fitness of the leader (which will fall with

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single physical plot; in such a case, a single physical plot will be counted as more than one plot for our analysis.

age) and may be associated with the leader's ability to undertake the strenuous demands of executing supervisory activities during the peak irrigation seasons. The *level of education of the managerial candidates* is measured at the community level as the percentage of the village labor force that has attained at least a high school education. The use of this variable depends on the assumption that managers that come out of such a pool would have a stronger inherent ability to organize collective activities. Descriptive statistics of the main variables in our study are in Appendix C.

Contractual Choices and the Nature of the Irrigation System

Similar to what Wang et al. (2005b) found, our data show that water management reform was implemented in some villages but not others (Table 2, rows 1 and 2). If villages that use fixed-wage contracts are categorized as unreformed villages, most of the reformed villages in our sample started to use either a profit-sharing or fixed-wage contract to manage the canals. In our sample, most of the reformed villages (82 percent) started to use either a profit-sharing or fixed-rent contract to manage their canals in either year 2000 or 2001. Other villages started earlier. For example, one village started to use a fixed-rent contract as early as 1995. Although a substantial share of leaders chooses either profit-sharing or fixed-rent contracts (17.5 percent and 37.5 percent), fixed-wage contracts are still the dominant form of canal management (45 percent). Hence there are still many villages in our sample that have yet to reform.

The descriptive statistics are largely consistent with predictions derived from theory. The contractual choices of the leaders seem to vary systematically with the nature of the village's cultivated land, the characteristics of the canal system, the human capital and the opportunity cost of the leader and a managerial candidate. When the degree of fragmentation of a village's cultivated land is high, the leader appears to be more likely to use a fixed-rent contract (Table 2, row 3). When the canals in a village's irrigation system are lined, villages apparently are less likely to be run as a fixed-wage contract (only 28 percent of the 18 irrigation systems with lining are run as fixed-wage contracts— row 5). In contrast, irrigation systems that have a higher propensity to silt up appear to be more likely to be run under fixed-wage contracts (row 6). In villages with fixed-wage contracts, the share of off-farm income in a villager's total household income is almost twice that of villages with fixed-rent contracts (42.9 percent versus 22.7 percent, row 8). Villages also appear to favor fixed-wage contracts when a greater share of the labor force out-migrates (row 9).

The descriptive statistics, however, also uncover some patterns that are not entirely consistent with the predictions. In examining more closely the relationship between the propensity to silt up and contractual choice, we observe an up-down-up pattern when moving from fixed-wage contracts (highest) to profit-sharing (lowest) to fixed-rent contracts (higher than profit-sharing and lower than fixed-wage). We find another type of nonlinearity in the relationship between the contractual choice and some of the covariates (e.g., with water abundance—Table 2, row 4; and age of leader—row 12). In these cases, we observe a down-up-down pattern when moving from fixed-wage contracts (lower than profit-sharing but higher than fixed-rent contracts) to profit-sharing contracts (highest) to fixed-rent contracts (lowest). It is possible that in Table 2 we are only observing two-way correlations and so we are not able to observe the true underlying relationships. In the next section, we then move to use multivariate analysis to examine more rigorously these relationships.

Explaining Contractual Choice in Canal Management: Multivariate Analysis

In order to measure the net contributions of possible factors identified in the last section and to statistically test the theoretical predictions from the contractual choice model, we run a series of multinomial, limited dependent variable regressions using the data that are available for our sample canals. Our empirical framework helps us answer the question: what factors in a particular locality induce the leader to choose to offer managerial candidates a fixed-wage, profit-sharing or fixed-rent contract.

Our dependent variable is a discrete outcome variable with three alternatives:

$$y = \begin{cases} 1, & \text{if fixed-wage cont ract is chosen} \\ 2, & \text{if profit-sharing contract is chosen} \\ 3, & \text{if fixed-rent contact is chosen} \end{cases}$$

Since the explanatory variables that we use are alternative invariant, a multinomial logit (MNL) model is used in our analysis. In equation form, the basic model can be written as:

$$p_{ij} = \Pr[y_i = j] = \exp(\mathbf{X}'_i \mathrm{b}_j) \Big/ \sum_{l=1}^{3} \exp(\mathbf{X}'_i \mathrm{b}_l), \quad j = 1, 2, 3.$$

where *j* is the index for the alternatives and *i* is the index for our observations. We include in the ***X*** vector those factors that we included in the descriptive analysis to test our predictions about the determinants of contractual form. We explain contractual choice as a function of the nature of the village's cultivated land; the design of the canal; the opportunity costs of the pool of managerial candidates and leaders and the human capital characteristics of the leaders and managerial candidates. Specifically, we use the degree of fragmentation and water abundance to test prediction 2. We use the canal lining, propensity to silt up and density of sluice gates to measure the characteristics of the canals in the village to test prediction 3. We use two measures of the relative opportunity cost of canal managerial candidates and leaders, the share of off-farm income and the proportion of migrants in the village, to test prediction 4. Finally, we use the human capital characteristics of leaders—the level of education and age of the village leader, and the average level of education of those in the pool of managerial candidates in order to test prediction 1.

Estimation procedure

Since we only have a small sample of data that we can use in our analysis (*n*=40), we may encounter some problems in the estimation.[16] First, there may be multicollinearity in the data. To check this, we conducted collinearity diagnostic to detect potential collinearity in the data (Besley, 1991). Fortunately, we only detected a minor collinearity in the data (the condition index was less than 100).

Second, we also tested various different specifications of the model (that is, combinations of the explanatory variables) to examine the robustness of the estimation results. The results show that although

[16] Although in our survey in 2001 we have collected data on 80 villages in three provinces (Hebei, Henan and Ningxia), we have only used the data collected in Ningxia province in this analysis for two reasons. First, in most areas in Ningxia province, surface water is the only source of irrigation water, which allows us to focus solely on the contractual forms that are used in managing canals. In contrast, in Henan province where both surface water and groundwater are used in irrigation; in Hebei province, the major source of irrigation water is groundwater and thus requires a different paper to study its managerial forms. Second, different villages in Ningxia province used different types of contracts to manage the canal systems. The variations in the way villages manage their canals offer a great opportunity to analyze the factors that have led to the differences in contractual choices. In contrast, in the surface water use areas in Henan province, most of the villages managed their canal systems in the same way (the fixed-wage contract) and so there was virtually no variation.

the absolute magnitudes of the coefficients of the same variable vary with different combinations of explanatory variables, the relative magnitudes, the signs and the significances of the coefficients are largely consistent.[17] Since the focus of our analysis is the directions of the impacts of the explanatory variables on the contractual choices of the village leaders, the variations in the magnitudes of the coefficients do not impair our analysis.

Given the differences in the estimation results generated by different model specifications, the natural question to ask is that which specification is the best. In the final step of the estimation procedure, we compare the prediction abilities of our models and out of the different specifications attempt to choose the "best" model for our analysis. Given that small sample size often causes the fit of the model (in-sample predictions) to be artificially good, the out-of-sample prediction is a relatively more reliable criterion on which to assess the accuracy of the estimates. Hence, we rely on the out-of-sample prediction to select the best model specification.

There are two stages in making the out-of-sample predictions: the estimation stage and the prediction stage. In the estimation stage, we remove randomly one village from the sample. The rest of the sample is used in the multinomial regression to estimate the parameters. In the prediction stage, the estimates are then used in conjunction with the value of explanatory variables of the village that was not used in estimation to predict the contractual choice of the village leader in that village. The contractual form with the highest probability is predicted as the village leader's choice of the contractual form. If the predicted contractual form of a village leader is the same as the contractual form the village leader actually chose (this is observed in the data), then we correctly predict the contractual choice of that village leader. This process is repeated for each village in the sample. Since there are 40 observations in our sample, we will repeat this process 40 times.[18] The percentage of sampled village leaders for whom the highest-probability contractual form and the chosen contractual form are the same is called the Percent

[17] Since the leaders are choosing from three different contractual choices, in the multinomial logit regression, there are two sets of parameters, one for each non-base alternative. The relative magnitudes refer to the relative values of these two sets of parameters.
[18] This is the leave-one-out cross validation procedure (Allen, 1974).

Correctly Predicted (PCP) measure.[19] The model with the highest PCP should have the property of minimizing the impact of the small sample problems on the results of the analysis.

Comparison of the values of PCP generated by different model specifications shows that models with fixed effects at the county level have higher values of PCP than models without fixed effects. Among the models with fixed effects at the county level, model 2 in Table 3 has the highest PCP. That is the basis of our choice of right hand side variables.

We also compare the values of PCP to the values in other studies. The PCP for is 50% for our best model. This is comparable to the values in other studies. For example, McFadden (1976) used a multinomial logit model to analyze the decisions of the California Division of Highways on the highway route. The values of his PCP measures ranged from 40.8% to 56.2%. The values of PCP ranged from 53.4% to 60.1% in the "best" models chosen by Matsukawa and Fujii (1994). It should be noted that both papers have larger sample sizes but only have used the in-sample prediction to generate the values of PCP. In summary, given the reason value of PCPs, our estimates are reasonably accurate and it is safe to make inferences based upon the estimates.

Econometric issues

The dependent variable in our regression is the contractual form current existing in the village in year 2001. Using the value from the same year may cause endogeneity problem for some explanatory variables. For example, how the canal is managed may affect the status of water resources in the villages. It also could have an effect on the crop income of households and thus may affect some of the explanatory variables such as the share of off-farm income. In the community leader questionnaire, as discussed above, we collected information for year 1990, 1995 and 2001. To avoid on possible effect of endogeneity, we chose to use 1995 values for some of the key independent variables (water abundance; the share of off-farm income; proportion of migrants). Although it is clear that the 1995 values of these

[19] The measure of PCP should be used with caution (Train, 2003). This measure is based on the idea that the villager leader is predicted by the researcher to choose the contractual form for which the model gives the highest probability. However, this is different from saying that the contractual choice with the highest probability will be chosen each time. Therefore, when we say we predict a village leader's contractual choice correctly, we mean that if the choice situation were repeated numerous times, the probability of predicting the village leader's contractual choice correctly is high. This is just a minor issue in our study because we mainly use it to compare the out-of-sample performance of different models so as to select the best models.

variables were pre-determined (prior to the contractual choice in 2001), the 1995 values are highly correlated with the values of the 2001 measures of the variables.[20] Thus, from this point of view, we can consider these to reasonable instruments. For other variables such as the canal lining, the propensity to silt up and the density of sluice gates, it is not likely that the reform could have induced any significant changes within such a short time. Since water managerial reform (both the profit-sharing and the fixed-rent contracts) mostly started in the year 2001, it is reasonable to assume these variables from year 2001 are exogenous in the multinomial logit model.

A potentially important drawback of the MNL model is the implicit assumption of independence of irrelevant alternatives property (IIA). This property states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternatives in the choice set due to the assumption that the cumulative distribution of the error term is logistic (Hausman and McFadden, 1984, Small and Hsiao, 1985). When we test whether the IIA property holds for our multinomial logit regression, the Small-Hsiao test fails to reject the null hypothesis of IIA. In addition, an alternative test, the Hausman test, fails to reject the null hypothesis of IIA. Therefore, we believe that it is safe to assume that the IIA property holds for our data and that a multinomial logit approach is appropriate.

Controlling for the heterogeneity among counties is likely to be important in satisfactorily explaining the contractual choice of the leaders, although it may create some statistical concerns. The reason is that there could be important unobserved effects (e.g., weather; governing philosophy of the local ruling leadership) that may affect the contractual choice of the leaders and may also be correlated with one or more explanatory variables. If these unobserved effects are not controlled for, the estimates may be biased and inconsistent. To control for such unobserved heterogeneity at the county level, we use a model with fixed effects at the county level. Unfortunately, allowing for fixed effects in a nonlinear discrete choice model, such as a probit or logit, may create a situation in which estimated coefficients suffer from an "incidental parameter problem" (Landcaster, 2000, Neyman and Scott, 1948). The reason

[20] The coefficient of correlation is 0.85 for the share of off-farm income variable, 0.82 for the proportion of migrants and 0.67 for the water abundance variable.

is that as the number of parameters (county dummies) increases with the sample size, the maximum likelihood estimation becomes inconsistent. Greene (2004), however, finds that although the bias is persistent, it drops off rapidly as the length of the panel (the number of villages per county in this paper) increases to three or more. Since there are, on average, eight villages per county in our sample, the bias from using fixed effects may not be a serious problem. To guard against the impact of using fixed effects with our multinomial estimator on our results, in Appendix D we also report the results of multinomial logit regressions without county dummies. Most signs of the coefficients do not vary between the two estimating approaches, although the magnitudes become somewhat larger when we include county dummies. Since we are interested in the leader's choice of one type of contract over another, in Table 3 we report coefficients that represent the relative probability of choosing one alternative over another.

Results

In general, our empirical estimations perform satisfactorily, especially given the fact that our sample is relatively small (Table 3). The goodness of fit measure, pseudo R^2, is around 0.9 for the multinomial logit equations with county dummies, which is quite high for analyses that use cross sectional data. The coefficients are also jointly significant.

Most importantly, many of our results support the predictions of our model and help us identify factors that induce some villages to run their irrigation systems under fixed-rent contracts while others run them under profit-sharing or fixed-wage contracts. For example, the multivariate analysis is consistent with prediction 2. The contractual choices vary systematically with the nature of the village's cultivated land. When the degree of land fragmentation is higher and there is a greater need for more complicated water delivery and closer supervision, the leader finds fixed-rent contracts more profitable (row 1, Table 3).[21] The relationship between water abundance and the contractual choices is also in line with prediction 2. The significant and increasing coefficients (in absolute value terms) that appear when moving from fixed-wage to fixed-rent equations show that the leader may find it optimal to offer the manager better

[21] It should be noted that the coefficients on the degree of fragmentation for the profit-sharing contract have the opposite sign in Model 1 and Model 2. This is the only major difference in the estimation results genarated by Model 1 and Model 2. Hence, we did not include the impact of the degree of fragmentation on the choice of profit-sharing contract here.

incentives when water resources become more abundant (row 2). Such a relationship may mean that when there is more water, there is likely to be less conflict over water and thus less need for the leader's skill at resolving the water-related conflicts. Moreover, with abundant water resources, there is more scope for the manager to utilize his skill at supervising water usage (e.g. managing the sluice gates in a way that avoids excess water loss). Savings on the volume of water as an input in providing irrigation services increase the level of profit and under such circumstances the manager is more likely to be willing to take a fixed-rent contract.

The signs on the other sets of variables are somewhat supportive of the other predictions. When looking at the effect of characteristics of the canal system on the decision to choose a fixed-rent contract versus a fixed-wage contract, our data support prediction 3 (Table 3, column 2). The positive sign on the canal lining variable demonstrates that as increasing investment improves the conditions of canals, the leader has a propensity to switch from a fixed-wage contract to a profit-sharing or fixed-rent contract (row3). On the other hand, the negative sign on the propensity to silt up variable indicates that a canal that often silts up and requires more cleaning makes the leader more reluctant to provide the managers with a fixed-rent contract (row 4). Likewise, the multivariate analysis shows that in canal systems with higher sluice gate densities the leader will have a higher probability of switching from fixed-wage to fixed-rent contracts (row 5).

Our estimated effects of variables representing the opportunity costs of the managerial candidates and the leader also are consistent with our theory (prediction 4). The negative sign on the coefficient of the share of off-farm income variable illustrates that when villagers have more access to off-farm activities, the leader is more inclined to run the canal system under a fixed-wage contract (row 6). Similarly, the coefficient on the proportion of migrants variable indicates that when there are more opportunities, i.e., to find an off-farm job outside the village, it is less likely that a managerial candidate will take a profit-sharing or fixed-rent contract (row 7).

While generally consistent with the basic model, the relative magnitudes (and in one case the sign) on the three characteristics of the canal system and on both of the opportunity cost variables show that there are nonlinearities in the relationship. For example, similar to the analysis of the descriptive statistics, as the propensity of the canal to silt up increases, the probability of selecting a profit-sharing contract (versus a fixed-wage contract) falls more than the probability of choosing a fixed-rent contract does (row 4). We also observe the same nonlinearities as the share of off-farm income or the proportion of migrants increases (row 6 and 7). It could be because the absence of an ability to commit such an effort on the part of either the leader or manager (or both) could reduce the probability of choosing a profit-sharing contract. For example, when the managerial candidates have more access to off-farm employment, they are likely to be able to generate higher earnings by working off-farm. In such a circumstance, they would have more of an incentive after taking a profit-sharing contract to shirk by spending as little time working on water management and as much time as possible off the farm. Knowing this, even though the characteristics of the canal and environment are such that profit sharing may be the optimal contractual arrangements (in the absence of imperfect information), the leader would be less inclined to offer the manager a profit-sharing contract.

Our results also contain nonlinearities that are consistent with the idea that the contractual arrangements between leaders and managers are affected by the role that profit sharing contracts can play in sharing risk. According to our basic theory, when canals are lined, collective activities play less of a role and so leaders, ceteris paribus, are more inclined to rent the canal system to an individual manager. The sign and significance of the coefficient of the canal lining variable in the fixed rent column of Table 3 (row 3) shows that our data provide support for this idea. However, the magnitude of the coefficient in the profit sharing column is even larger than that in the fixed rent column (and statistically different). If leaders in such systems are willing to rent out the canal system, but managers, who are risk averse, are less willing to accept such an offer (because of the risk they assume as the contractor), it could be that the leader finds it optimal to engage the services of the manager as a profit sharing contract. In this case, although the incentives for the manager are less than they would be had the manager accepted a fixed-rent contract, the additional risk sharing offered by the profit sharing contract is enough to get more managers to accept a managerial role.

Multivariate analysis also provides some support for prediction 1: the optimal contractual choice depends on the relative abilities of the leader and potential managers. The negative signs on the coefficients of the level of education of the leader indicate that more capable leaders are more likely to run the canal system by themselves under a fixed-wage contract (row 8). In contrast, when the pool of managerial candidates is better educated and thus has higher ability to run the irrigation system, leaders are more likely to choose a profit-sharing or fixed-rent contract (row 9). Older leaders may be less able to manage the canal system (due to need to exert high levels of effort). Hence, older leaders are more likely to switch to contracting (row 10). As above, however, the basic theory is not complete, since there is some evidence that our results are consistent with the idea that profit sharing contracts are in fact demanded since they reduce risk.

Conclusion

The main purpose of our paper is to explain the puzzling fact that in pursuing water management reform, leaders have provided incentives to managers in some areas, but not in all. Our findings indicate that one of the reasons that not all leaders provide strong incentives stems from the specific characteristics of the irrigation system. If the conditions of canals do not allow for profitable operation of the canal under a profit-sharing or fixed-rent contract, the leader would not be motivated to lease out the canal to the manager. In addition, the nature of the village's resources and its economic environment as well as the characteristics of its leaders and the pool of possible managers will affect contract choice. While the absolute advantage-based explanation for the determinants of contractual choice explains much of what we observe in rural China, the findings also suggest that contractual choice may also depend on risk sharing and imperfect information.

Regardless of the exact determinants of contractual choice, our findings do help explain why even though strong incentives promote water savings, they are not used in all villages. The simple answer is that they are not appropriate to all villages. Hence, in China's future design of water management reforms, policy implementation should depend on the local conditions of the villages and it should be recognized that not one reform path fits all villages. Concretely, when designing policies on water management reform, instead of simply requesting leaders to provide incentives, China's policymakers need to take into account the features of the area where the reform is going to take place.

Our results also have implications for the design of China's broad water reform strategy. According to our results, water management reform has potential to work in some areas. Hence, it should be encouraged. However, in other areas reforms will not be appropriate. In such areas pushing water management reform will not only be difficult, but may produce negative results if forced. Losing the leader's active participation could be counterproductive in village's that need collective action to be mobilized. In these other villages, if water is to be saved, upper-level policy officials may have to look beyond water management reform. In general this means that a more integrated water reform strategy, using water management reform (with the support of complementary policies in some areas) and focusing mostly on complementary policies in others may be more successful in the long run.

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Figure 1. Optimal contratual forms under varying degrees of comparative advantage for village leader- and canal manager- supplied inputs

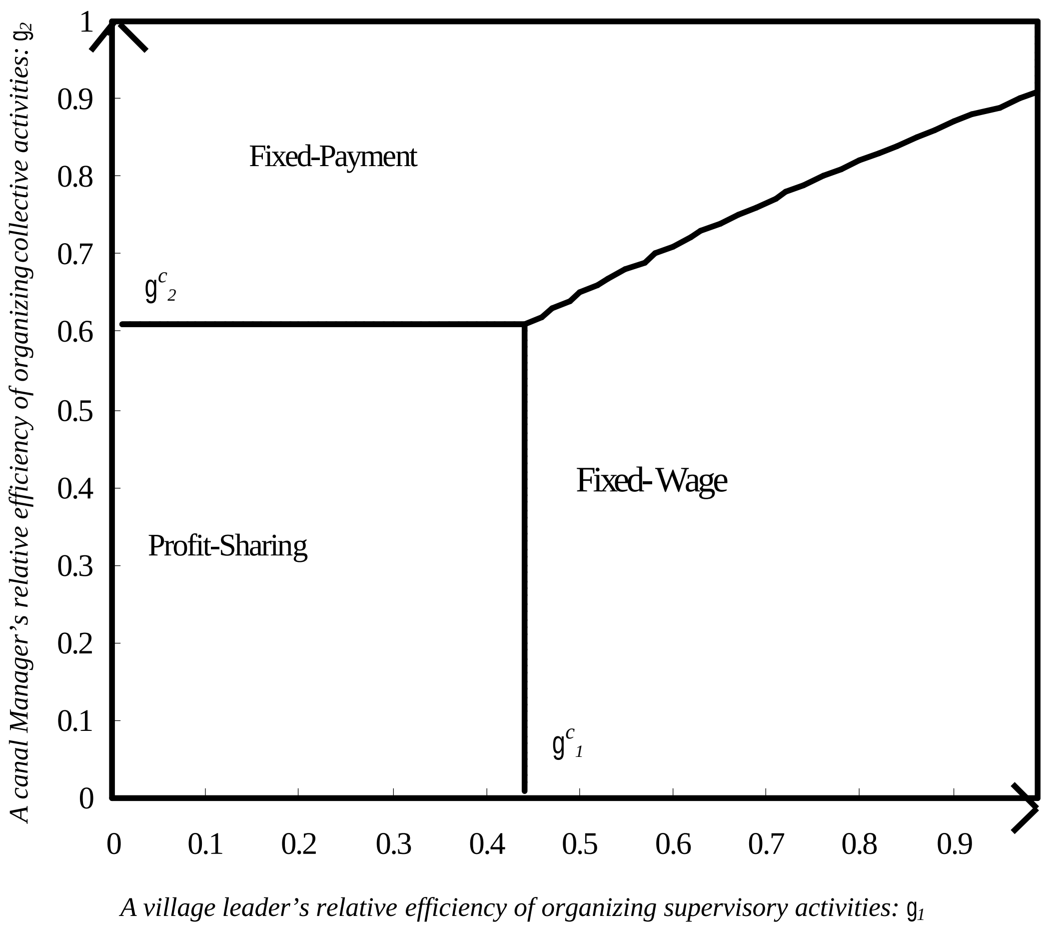

Figure 2. Simulations of Impacts of Different Factors on Critical Values of Relative Efficiency

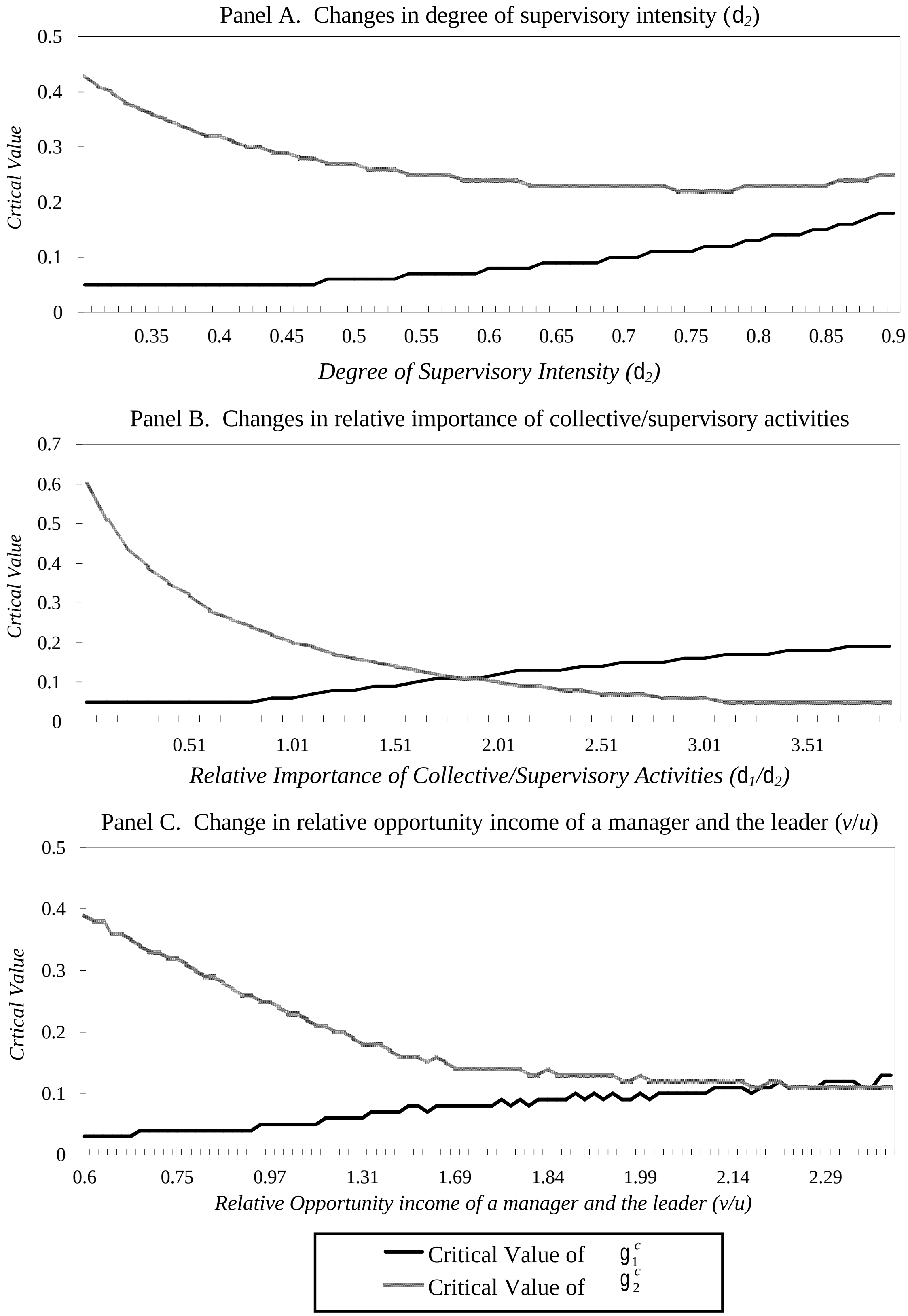

Table 1. Estimates of production function parameters for use in simulations

$$Q = At^{d_1}s^{d_2}L^{d_3}W^{d_4}H^{d_5}, \quad \text{CRS: } d_1+d_2+d_3+d_4+d_5=1.$$

	Without fixed effects	With fixed effects at irrigation district level	**With fixed effects at county level**
Time spent on collective activities (*t*)	0.006	0.002	**0.015**
	(0.23)	(0.10)	**(0.54)**
Time spent on supervisory activities (*s*)	0.134	0.174	**0.174**
	(2.10)**	(2.57)**	**(2.31)****
Amount of labor (*L*)	0.050	0.059	**0.043**
	(1.75)*	(2.07)**	**(1.37)**
Amount of water purchased (*W*)	0.774	0.724	**0.725**
	(8.43)***	(7.57)***	**(6.64)*****
Length of the canal that is lined (*H*)	0.036	0.040	**0.043**
	(1.61)	(1.84)*	**(1.88)***
Constant	7.932	7.762	**8.091**
	(35.46)***	(31.67)***	**(15.26)*****
Observations	40	40	**40**
R-squared	0.9807	0.9820	**0.9837**
Number of IDs		2	
Number of counties			**5**

a. All variables are in log form.
b. *t*, *s* and *L* are all measured using the unit of a labor day.
c. Absolute value of t statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 2. Characteristics of canals, water resources, village leaders, and villages under different water managerial forms (Ningxia Province, China 2001)

	Managerial form	Fixed-wage	Profit-sharing	Fixed-rent
1	Number of observations	18	7	15
2	Percentage	(45)	(17.5)	(37.5)
Condition of the Natural Environment				
3	Degree of fragmentation (number of plots/ household)	6.76	7.89	9.98***
4	Water abundance (index—4 if abundant; 1 if scarce)	3.61	3.71	3.53
Characteristics of the Canal System				
5	Canal lining (1 if lined, 0 otherwise)	0.28	0.29	0.53*
6	Propensity to silt up (1 if yes, 0 otherwise)	0.61	0.14**	0.60
7	Density of sluice gates (number/km)	41.54	22.60	38.19
Opportunity Cost of the Pool of Managerial Candidates				
8	Share of off-farm income (%)	42.90	27.71**	22.67***
9	Proportion of migrants (% , share of village labor force that out migrate)	21.55	14.23*	14.33*
Human Capital Characteristics (ability proxies)				
10	Level of education of the leader (attainment in years)	9.28	8.86	8.47
11	Level of education of the managerial candidates (%, share of labor force with at least high school education)	44.81	44.89	45.41
12	Age of the leader (years)	44.67	45.43	41.93

a. * denotes the difference between the mean under profit-sharing or fixed-rent contract and under a fixed wage contract is significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3. Multinomial Logit regressions explaining contractual choice by the village leader in Ningxia Province
(With fixed effects at county level)

		Model 1		Model 2	
	Base category: Fixed-wage	Profit-sharing	Fixed-rent	Profit-sharing	Fixed-rent
Condition of the Natural Environment					
1	Degree of fragmentation (number of plots/ household)	19.15	87.48	-49.326	23.779
		(6.31)***	(13.95)***	(3.33)***	(3.49)***
2	Water abundance (index—4 if abundant; 1 if scarce)	141.40	190.12	33.924	55.922
		(13.63)***	(14.46)***	(2.65)***	(3.07)***
Characteristics of the Canal System					
3	Canal lining (1 if lined, 0 otherwise)	447.38	420.75	134.835	108.493
		(14.02)***	(13.73)***	(3.73)***	(3.64)***
4	Propensity to silt up (1 if yes, 0 otherwise)	-148.97	-9.18	-237.693	-2.591
		(16.68)***	(6.29)***	(3.33)***	(1.11)
5	Density of sluice gates (number/km)	-0.04	0.09		
		(2.77)***	(6.30)***		
Opportunity Cost of the Pool of Managerial Candidates					
6	Share of off-farm income (%)	-21.53	-18.60	-14.913	-4.999
		(14.92)***	(13.87)***	(3.45)***	(3.42)***
7	Proportion of migrants (% , share of village labor force that out migrate)	-7.24	-0.30		
		(15.80)***	(1.45)		
Human Capital Characteristics (ability proxies)					
8	Level of education of the leader (attainment in years)	-55.15	-55.26	-0.313	-13.201
		(13.05)***	(12.64)***	(0.14)	(3.51)***
9	Level of education of the managerial candidate (%, share of labor force with at least high school education)	18.54	18.25	-0.504	4.687
		(13.49)***	(13.62)***	(0.79)	(3.66)***
10	Age of the leader (years)	45.54	32.54	20.996	8.316
		(14.79)***	(13.13)***	(3.54)***	(3.60)***
	Observations	40		40	
	Log likelihood	-2.945		-15.63	
	Percent Correctly Predicted (Out-of-sample)	**43**		**50**	

Robust z statistics in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix A. Model of water managerial form choice

To avoid complicated expressions, we use $f(.)$ to denote the Cobb-Douglas production function defined in the paper. Production of irrigation services may be expressed as:

$$Q = \theta\, f(t, s, L, W, H) \tag{A1}$$

where f is assumed to be linearly homogeneous, increasing, and concave in its first five arguments. Other symbols are the same as defined in the paper.

The model is based on the assumption that the leader and the manager each has one unit of the time that must be allocated between irrigation service provision and their alternative activities. The opportunity income of leader is v, and that of the manager is u. Wage rate of hired labors is w, water fee is r per cubic meter, and P is the price of irrigation services. The price, P, is constant in the model since each household pays the same price within the same village and there are only small variations in the prices of water during different irrigation season within the same year. The parameters, v, u, w, r, and P are all assumed to be exogenously determined, and the labor market is competitive. In addition, since water is not charged volumetrically within the village, it is not possible for us to analyze the relationship between the price of water and the volume of water household demands. Hence, instead of directly analyzing the household water demand, in our study, we take into account the household water demand by including a lower bound of the output. The lower bound is the minimum amount of irrigation services that must be provided to households ($\overline{Q}$) both in the quantity and in the timing and frequency of water deliveries.

Under a *fixed-wage contract*, the leader maximizes expected net income (denoted by superscript fw):

$$\pi_1^{fw} = \max_{t_1, s_1, W, L} \left[Pf(t_1, \gamma_1 s_1, W, L, H) - rW - wL \right] + (1 - t_1 - s_1)v$$

$$s.t. \qquad 0 \le t_1 \le 1, 0 \le s_1 \le 1, 0 \le t_1 + s_1 \le 1. \tag{A2}$$

$$Q \ge \overline{Q}$$

Under a *fixed-rent contract (individual contracting)*, the expected net income of the manager prior to paying the rent is (denoted by superscript fp):

$$\pi_2^{fp} = \max_{t_2, s_2, W, L} \left[Pf(\gamma_2 t_2, s_2, W, L, H) - rW - wL \right] + (1 - t_2 - s_2)u$$

$$s.t. \qquad 0 \le t_2 \le 1, 0 \le s_2 \le 1, 0 \le t_2 + s_2 \le 1. \tag{A3}$$

$$Q \ge \overline{Q}$$

Given the existence of a perfectly elastic supply of managers and competitive contract bidding, the rent will be bid up until the manager is at (or marginally above) his opportunity income, u. Thus, the fixed-rent to the leader is:

$$R = \max\left\{0, \pi_2^{fp} - u\right\} \tag{A4}$$

and leader 's income is:

$$\pi_1^{fp} = v + R \tag{A5}$$

Under a *profit-sharing contract*, the leader and a manager each provide one of the unmarketed inputs and the profit is shared according to some endogenously determined, but mutually agreed upon rule. For the purpose of tractability, we make the assumption of complete specialization.

Define the restricted expected profit function, $\pi(t, s)$, which is obtained by optimally choosing W and L for parametrically given t and s:

$$\pi(t, s) = \max_{W, L} Pf(t, s, W, L, H) - rW - wL \tag{A6}$$

Under the most general of profit-sharing rules, the manager gets:

$$S_2 = \alpha + \beta\pi \tag{A7}$$

where α and β are constants to be endogenously determined. At the same time, leader gets:

$$S_1 = -\alpha + (1-\beta)\pi \tag{A8}$$

Under these circumstances, the manager and the leader choose s_2 and t_1 to maximize their expected income by solving:

$$\max_{s_2} \beta\pi(t_1, s_2) + (1 - s_2)u \qquad s.t. \quad 0 \le s_2 \le 1 \tag{A9}$$

and:

$$\max_{t_1} (1-\beta)\pi(t_1, s_2) + (1 - t_1)v \qquad s.t. \quad 0 \le t_1 \le 1, \quad Q \ge \overline{Q} \tag{A10}$$

Equations (A9) and (A10) will give the best response functions:

$$s_2 = \sigma(t_1; \beta) \qquad t_1 = \tau(s_2; \beta) \tag{A11}$$

At a Nash equilibrium pair [$t_1^*(\beta), s_2^*(\beta)$], which is shown in Eswaran and Kotwal (1985) to exist and assumed to be unique, equation (A9) and (A10) are simultaneously satisfied.

Before making the final agreement on a set of endogenously determined contractual terms, leader chooses β to maximize expected income as long as the manager's expected income is no less than his opportunity income. The endogenously determined value of β^* is the β that solves:

$$\max_{\beta} \left\{ -\alpha(\beta) + (1-\beta)\pi[t_1^*(\beta), s_2^*(\beta)] + [1 - t_1^*(\beta)]v \right\} \tag{A12}$$

where α(β) satisfies the following relationship

$$\alpha(\beta) + \beta\pi[t_1^*(\beta), s_2^*(\beta)] + [1 - s_2^*(\beta)]u = u \tag{A13}$$

The leader's expected income is thus:

$$\begin{aligned} \pi_1^{ps} &= -\alpha(\beta^*) + (1-\beta^*)\pi[t_1^*(\beta^*), s_2^*(\beta^*)] + [1 - t_1^*(\beta^*)]v \\ &= \pi[t_1^*(\beta^*), s_2^*(\beta^*)] + [1 - t_1^*(\beta^*)]v + [1 - s_2^*(\beta^*)]u - u \end{aligned} \tag{A14}$$

Interestingly, in our sample villages, in 4 out of the 7 villages that used a profit-sharing contract in year 2001, the profits were split 50:50 between the leader and the village leader. In the rest villages, the shares of profit that the manager claimed were around the level of 50% (35%, 56% and 63%). The profit shares from the simulation results vary depend upon the values of parameters (e.g, the opportunity costs of a manager and the community leader, *u*/*v*). Interestingly, the observed level of profit shares, like those in Eswaran and Kotwal (1985), are near the level of 50%.

After solving each of these maximization problems (equation (A2), (A5) and (A6-12)) ex ante, the criteria used by leader to choose managerial form is simple: compare expected income under all three contract forms, Equation (A2), (A5) and (A14), and choose the contract that maximize his expected income.

Appendix B. Time spent on collective and supervisory activities per unit length of the canal in year 2001 (Unit: labor day / meter)

Water managerial form	Fixed-wage	Profit-sharing	Fixed-rent
Time spent on carrying out collective activities	0.23	0.02	0.29
(*t*)	(0.37)	(0.03)	(0.48)
Time spent on carrying out supervisory activities	0.04	0.04	0.05
(*s*)	(0.07)	(0.02)	(0.05)

*Standard deviations in parentheses.

Appendix C. Descriptive statistics of variables.

		Number of observation	Mean	Standard Deviation	Minimum	Maximum
1	Indicator variable for types of contracts [a]	40	1.93	0.92	1	3
2	Degree of fragmentation	40	8.17	3.49	2.25	15.5
3	Water abundance	40	3.60	0.74	2	4
4	Canal lining	40	0.38	0.49	0	1
5	Propensity of siltation	40	0.53	0.51	0	1
6	Density of sluice gates	40	36.97	56.61	0	232.60
7	Share of off-farm income	40	32.66	19.58	0	80
8	Proportion of migrants	40	17.56	13.81	0	59
9	Level of education of the leader	40	8.90	2.72	0	12
10	Level of education of the managerial candidate	40	45.05	13.53	15	70
11	Age of the leader	40	43.78	7.32	32	57

a. If =1, fixed-wage; if = 2, profit-sharing; if = 3, fixed-rent.

Appendix D. Multinomial Logit regressions explaining contractual choice by the village leader in Ningxia Province
(Without fixed effects)

		Model 1		Model 2	
	Base category: Fixed-wage	Profit-sharing	Fixed-rent	Profit-sharing	Fixed-rent
Condition of the Natural					
1	Degree of fragmentation	0.005	0.562	0.094	0.569
		(0.02)	(1.94)*	(0.33)	(1.86)*
2	Water abundance (index—4 if	2.426	1.107	1.575	1.015
		(2.38)**	(1.35)	(1.49)	(1.15)
Characteristics of the Canal System					
3	Canal lining (1 if lined, 0	2.211	3.643	2.456	3.560
		(1.29)	(1.76)*	(1.56)	(2.09)**
4	Propensity to silt up (1 if yes, 0	-4.631	1.081	-3.572	0.969
		(2.03)**	(0.91)	(1.75)*	(0.79)
5	Density of sluice gates	-0.018	-0.003		
		(1.77)*	(0.34)		
Opportunity Cost of the Pool of					
6	Share of off-farm income (%)	-0.166	-0.138	-0.210	-0.152
		(2.02)**	(1.78)*	(2.85)***	(2.05)**
7	Proportion of migrants (% , that out migrate)	-0.067	-0.038		
		(1.30)	(0.90)		
Human Capital Characteristics					
8	Level of education of the leader	0.354	0.260	0.375	0.064
		(1.94)*	(1.70)*	(1.42)	(0.27)
9	Level of education of the share of labor force with at least	0.299	0.050	0.078	0.107
		(1.16)	(0.22)	(1.48)	(1.73)*
10	Age of the leader (years)	0.026	0.101	0.407	0.256
		(0.51)	(1.61)	(2.55)**	(1.74)*
	Observations	40		40	
	Log likelihood	-23.579		-23.378	
	Percent Correctly Predicted (Out-of-sample)	**33**		**38**	

Robust z statistics in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%