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Water Management Reform and the Choice of Contractual Form in Rural China

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When irrigation systems perform inefficiently, they not only waste water, but also may affect agriculture production and rural incomes, especially in regions facing water shortages. In rural China only 40 percent of the water that is allocated to irrigation is effectively used, a figure much lower than many developed countries (Wang, 2000). Although the inefficiency of 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 poor performance (Wang et al., 2003).

In confronting problems with China's irrigation systems, leaders have begun experimenting with new institutional forms to manage water in rural communities. Since the late 1990s, policy makers have promoted 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) to private individuals (typically farmers from the village).

The record on reforms, however, seems to be mixed, although most evaluations are only based on anecdotes or small case studies (Nian, 2001; Huang, 2001; China District Irrigation Association, 2002). Some observers have reported that the process of water management reform has been successful (Easter and Hearner, 1993). 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).

In one notable exception, Wang et al. (2003) studies a set of villages randomly selected from irrigation districts in the Yellow River Basin and finds that the success of water management reform in China is positively correlated with the incentives that are provided to the managers. These incentives are measured by the share of profits from operating the irrigation system that the canal manager is able to claim. Their findings demonstrate that in villages that provide individual canal managers with strong incentives to save water, their water use falls sharply while having almost no effect on agricultural production or rural incomes. In contrast, when villages do not provide incentives, canal managers do not save water. In other words, the provision of incentives to water managers appears to have succeeded in improving the efficiency of the irrigation system.

One question Wang et al. (2003) do not answer, however, is that if incentives work so well, why is it that all villages do not provide them to their managers. Their data show that when promoting water management reform, village leaders provide canal managers with incentives in some areas, but not in others. During our fieldwork, we have made similar observations. There is great heterogeneity across villages in how canal systems are managed. Some villages have chosen to stay with the traditional form of village leader-run irrigation management. In these villages, the village leader is in charge of both *collective activities*, such as maintaining canals and resolving water conflicts, and *supervisory activities*, such as monitoring water allocation and collecting water fees. The village leader either manages the whole system by herself, as part of her regular duties or hires a canal manager for a fixed wage to perform some of the water management tasks under her direct instructions. Under such a *fixed-wage* contract, however, the canal manager does not have a strong incentive to put out effort since he does not get any portion of the profit from operating irrigation system and is not really expected to take much initiative.

While fixed-wage contracts may work fine in villages with irrigation systems that need the village leaders to use their authority to coordinate collective tasks (i.e., villages that have canal networks that require a lot of maintenance and thus require someone to coordinate the collective action that is necessary to clean the canals), having the village leader as the principal manager of the canals may have a cost and may make the village leader seek other ways to manage the village's canal system. Burdened with many other duties, such as implementing family planning programs and managing the village's land or enterprises, the village leader often cannot afford to devote her full attention to operating canals. This would especially be the case in a village in which the nature of the cropping patterns or land allocations are such that they require intensive supervision during irrigation. Perhaps in response to such pressures, some village leaders have transferred complete control and income rights of the village's canal network to a private individual on the basis of a *fixed-payment* 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 canal manager follows the rules and regulations set by the village leader, provides quality irrigation services, and makes his fixed payment, the village leader usually does not intervene directly in the day-to-day canal management tasks. Finally, in other villages, the leader and the hired manager share both responsibilities and the profits from the irrigation tasks, a form of management that can be called a *profit-sharing* contract.

In this paper, we argue that the answer to the question raised by Wang et al. (2003) -- why village leaders do not provide incentives in all areas -- can be found by examining the conditions under which certain contracts work well while others do not. We believe our line of inquiry helps extend the literature on water management reform. While researchers have shown the effectiveness of water management reforms in improving the efficiency of water use, no one has yet tried to explain why different villages have reacted differently.

In this paper, we take on the challenge of developing a better understanding of how China has implemented successfully its nascent water management reforms. Following Eswaran and Kotwal (1985), a paper that develops a model explaining the choice of contract form in land tenure contracts between landlords and tenants on the basis of *unmarketed inputs*, we develop a theory that treats the different ways in which village's manage their irrigation systems under different contractual forms. The contracts differ in the ways in which village leaders and canal managers combine different unmarketed inputs to carry out the management responsibilities of the village's canal system. In our case, the unmarketed inputs are a.) the skill and/or authority that it takes to *organize collective activities*, such as the maintenance of canals or the resolution of water disputes among individuals; and b.) the skill and/or time that it takes to *supervise effort-intensive activities*, such as the coordination and execution of water deliveries or the collection of water fees. Under the key assumption that village leaders and canal managers have comparative advantages in providing one of the two unmarketed inputs, our model explains what motivates profit-maximizing (or efficiency-oriented) village leaders to choose one type of contractual form in certain villages and another type in others. The main decision that village leaders must make is to decide which party (the leader herself or manager) can run the irrigation system most efficiently and to provide that party with the incentives and control rights to do so. If the village leader operates in such a way, she will be more likely to choose a fixed-payment contract in irrigation systems that require a lot of supervision-intensive activities, since the canal manager is better at organizing such activities. In contrast, the village leader would be more likely to choose a fixed-wage contract and run the village's canal system herself (or at most with the aid of a wage-earning manager) in villages that require more collective activities, such as those with canal networks that require a lot of maintenance.

Of course, the leader also has to consider the opportunity cost of her decisions. For example, even in villages that might operate more effectively under a fixed-payment contract (because there was a need to supervise effort-intensive activities), if all available candidates for the canal manager position also have access to lucrative off farm activities, to induce an individual from the pool of potential canal managers to accept a contract, the village leader likely would have to lower the level of the fixed payment (in order to provide the manager with higher compensation). Under such circumstances, the village leader might still choose to manage the canal system by herself, even though she supervises less efficiently.

To try to better understand water management reform in China, the overall goal of our paper is to provide a framework for explaining the choice of canal managerial forms that govern water management in rural China. To meet this 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 irrigation system and the characteristics of its leaders and canal managers. Second, we seek to empirically identify the factors that may induce the village leader to choose one type of a contractual form over another by using both descriptive statistics and multivariate analysis.

The data for our study come from a survey that we conducted in thirty-two randomly chosen villages within two irrigation districts (IDs) in Ningxia province, which is located in the upper reaches of the Yellow River Basin. In selecting the villages for our study, we considered a number of criteria. We chose the IDs based largely on water availability, doing so by selecting one in the upstream part of the province and one in the downstream part. After selecting the IDs, we randomly chose villages from a census of villages in the upper, middle and lower reaches of the canal network within each ID. In our extensive interviews and formal surveys with the leader and individual canal managers within each sample village, enumerators asked detailed information on canal contractual form and management activities. In particular, we asked about the responsibilities of the canal manager and how the managers were compensated -- that is, the share of the profit from operating the irrigation system that they received. The survey also collected information on water use, the degree of water scarcity and the level of investment in the village's irrigation system over the past 20 years, as well as a number of other village, household and plot characteristics. Descriptive statistics of the main variables are shown in Appendix A.

Modeling Managerial Choice in Rural China

The managerial contract between the village leader and canal manager governs not only each party's responsibilities in the operation and maintenance of canals, but also their rights to claim the residual profits from irrigation services. In other words, canal managerial forms determine how the skills of the individuals are utilized in the operation and maintenance of canals and define the economic incentives faced by those involved, two elements that will have an important bearing on the ultimate performance of the irrigation systems and the profitability of irrigation services. Such contracts must be established at the nexus of mutual inter-dependence, but since ultimate property rights reside with the village leader as the curator of local assets, the village leader will make the choice on the contractual form that will further her interests.

Such a characterization is reasonable in the context of rural China's transition. Since officials implemented a set of policies (called the rural financial reforms by Oi, 1999; Whiting, 2001; and Rozelle, 1994), village leaders have been encouraged to use village assets, including the irrigation system, efficiently and are allowed to run them, where appropriate, on a fee for service basis. Importantly, the policy implicitly allows the village leader to claim a reasonable profit from such service-oriented activities. As a consequence, we believe it is not unreasonable to assume that the village leader's interests frequently are consistent with profit-maximization. To *make a profit* from the village's irrigation system (or at least to operate it efficiently), the key decision the village leader needs to make is to put the individual who can run the irrigation system most efficiently in charge and to provide them with the incentives to do so.

In developing a model in which the village leader endogenously chooses the optimal contractual form based upon the nature of the canal system and other factors, we make two basic assumptions. First, the village leader and canal manager have their own comparative advantage in being able to perform one of the two activities that are required to run an irrigation system. As the local authority, the village leader is efficient at organizing collective activities such as mobilizing the labor of her villagers to clean canals, coordinating irrigation schedules among households and resolving water conflicts. Using her executive authority, the village leader can easily (at least in relative terms compared to any individual farmer) mobilize households within the village to clean and perform other maintenance work on the village's canal system on a seasonal or annual basis. If an individual canal manager were in charge of maintaining the canals on his own, he would almost invariably have to hire laborers from inside or outside of the village to help him do so.

In contrast, we assume the canal manager is endowed with a superior ability (and more time) to supervise effort-intensive operations. For example, while there are no reasons to believe that village leaders also could not effectively manage water allocation operations if they had the time, one of our key points is that they often do not have the time. Since the village 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, she almost assuredly is less able to provide the concentrated effort and attention to detail that is needed in certain villages to allocate water and other irrigation services. A full time canal 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, canal 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 will often try to use many excuses to avoid or delay payment to the village leader or her accountant, often playing on the fact that village is at least partly responsible for providing welfare functions to needy villagers. These tactics are less effective when canal managers, who themselves are farmers, come to collect for services rendered.

Our second key assumption is that the ability to organize collective activities or supervise effort-intensive activities is unmarketable. In other words, a busy leader in a village with an irrigation system that requires a lot of supervision of effort-intensive operational management cannot purchase the supervisory services on the market. Likewise, a canal manager can not procure collective action on the market to help him with tasks such as canal maintenance or dispute resolution.

Under these two basic assumptions, we can characterize the relationship between the village leader and canal manager as a contract in which each party provides unmarketable inputs. One of the salient features of the relationship is that each party has an advantage in providing one of the inputs that the other party does not have or cannot provide as efficiently. Since the inputs brought by one or both parties are not available for purchase on the market, then to the extent that each factor is needed for the profitable operation of the irrigation system, it becomes necessary to devise a way that will induce each party to provide and use the input in the enterprises as effectively as possible. The extent of participation by each party, as defined in the contract, depends on the relative importance of the activities they have the comparative advantage in being able to perform.

The relative importance of different activities depends heavily on the *technology* within the irrigation system. During our visits to the field, we observed a great deal of heterogeneity in the construction, design and general nature of canal systems. We also noted that there was a great deal of difference between villages with respect to the amount of time that was allocated to the provision of collective or supervisory tasks. For example, some canal systems have little or no cement lining. In others, water resources are scarce. In such systems, there is almost certainly a great need for organizing collective activities, such as canal maintenance and the resolution of conflicts when they arise because water is in short supply. By contrast, in other villages, the canal system winds intricately through fields of highly fragmented plots and households are spread out spatially. In these villages, the irrigation systems require more supervision of effort-intensive tasks such as frequent deliveries of water to meet the special needs of farmers (that are producing different crops on their fragmented plots) and additional effort towards the collection of water fees. Finally, some systems require both collective and supervisory activities.

Given these assumptions, the characteristics of the canal system, the village and both the leaders and managers will play a role in determining how canal systems are managed. If collective activities are more essential for effective canal operation than supervisory activities, one might expect to find it being run under a fixed-wage contract. In a fixed wage contract, the village leader is primarily responsible for the irrigation system and spends most of her time providing the collective activities, such as canal maintenance. If, on the other hand, the collective activities provided by the village leader are relatively less valuable and if the village leader is busy with other duties such as running township and village enterprises or implementing family planning programs, then the village leader's contribution towards efficiently running the irrigation system may be relatively less valuable. Under such circumstances, one might expect to find the irrigation system being run under a fixed payment contract. When operating under a fixed payment contract, the canal manager will work hard to provide the day-to-day supervisory activities needed to allocate water to the system's farmers. In such a system, the village leader only has to collect the rent and let the canal manager run the canal.

A third, middle-ground case might also exist. In irrigation systems that require both collective and supervisory activities, both inputs may be needed and of equal importance. For example, the village may have a canal network that requires a lot of maintenance (a collective activity), but be in an region that has a set of crops which demand a lot of attention from the canal manager (a supervision-intensive activity). In this case, the village leader may find it profitable to perform collective activities and rely on a canal manager for supervisory activities. If this division of responsibilities is chosen, it may be that a team effort is the best way to manage the canal system. Since it is difficult for each party to monitor the other's contribution, under such an arrangement, the leader may want to offer an arrangement in which both she and the manager share the profits, or run the irrigation system under a profit sharing contract.

The characteristics of village leaders or canal managers may also, in part, determine the contractual choices of village leaders. For example, if the canal manager in the village is good at organizing collective activities (e.g., they may be a former village leader) as well as supervisory activities, village leaders may offer a fixed-payment and let the canal manage take all the responsibilities for operating the canals. In other villages, such as those with convenient access to non-farm activities, the opportunity cost of the canal manager in managing canals may be high. In this case, even if the canal manager might be good at supervisory activities, it may be that the village leader will not offer a fixed-payment contract because he would have to reduce the amount of the fixed payment to an extremely low level so as to induce the canal manager to accept the contract. Even if the canal system needed a managers with relatively strong abilities to deliver supervisory activities, the village leader might have to do it herself in a village in which no canal managers would take a fixed payment contract.

Model

Our analysis begins with the specification of a production function of irrigation services (Q). Irrigation services generally include the water that is delivered to the farmers' fields at the times and in the quantities that they need. Delivering irrigation services requires a set of inputs. Besides the *water* (W) that is delivered to farmers through the system's *infrastructure* (H), lined or not, several other inputs are needed. First, time is needed to organize the collective activities (t). Second, effort (E) to operate the system also is needed and consists of two parts: labor (L) to carry out the activities; and supervision (s) to monitor the labor and supervise the operation of the system.

Given these variables, we can relate the inputs to the output of irrigation services using the Cobb-Douglas production function:

(1) $Q = At^{\delta_1} E^{\delta_2} W^{\delta_3} H^{\delta_4}$; and $E = s^{\varepsilon} L^{1-\varepsilon}$,

where δ_1 to δ_4 and ε are the parameters that represent function coefficients.

Under the assumption that the village leader has a comparative advantage in organizing collective activities and that the canal manager has a comparative advantage in supervisory activities, we define the time a village leader spends on collective activities as t_1 (where 1 refers to the leader for the rest of the paper) and define the time a canal manager spends on collective activities as t_2 (where 2 is denotes the canal manager). By assumption, $t_1 > t_2$. In our model, we use γ_2 as a relative efficiency parameter that denotes the relative efficiency with which the canal manager organizes collective activities vis-à-vis the village leader. We allow γ to vary from 0 to 1, and recognize that in our model $t_2 = \gamma_2 * t_1$. According to this expression, if the canal manager spends one unit of time organizing collective activities, it is equivalent to the village leader (who is better at collective action) spending γ_2 unit of time. Likewise, the time the village leader spends on activities such as supervision, s_1, is not as effective as time spent by the canal manager, s_2. And so, using the same notation as above, $s_1 = \gamma_1 * s_2$, which means that in our model, if the village leader spends one unit of time in supervisory activities, it is equivalent to the canal manager (who is better at supervision) spending γ_1 unit of time.

Although both the village leader and canal manager contribute to the management of canals, we assume that the village leader is the one who makes the choice of canal managerial form because he is the curator of local assets. In other words, the village leader decides if her village's irrigation system is managed as a fixed wage, fixed payment or profit sharing contract. Since the village leader shares in the profits of the village's activities and is rewarded for building the village's treasury (Oi, 1999; Whiting, 19XX; Rozelle, 1994), we assume that the village leader chooses the contract that will return to her the highest level of profits. In other words, in our model of China's irrigation management, we believe the village leader of each village considers the production function of irrigation services (equation 1), the characteristics of her village, her own characteristics and the characteristics of canal managers and solves three different "problems" for herself: how much profit would I make if I ran the irrigation system myself (as a fixed wage contract); how much rent could I make if I leased it out (as a fixed payment contract), and how much profits would be left for me if I split the duties and profits with a canal manager (under a profit sharing agreement). Details of the model and calculations of the profits that can be generated when the canal is managed under different contractual forms are found in Appendix B.

Operationalizing the model

In creating a model of the village's irrigation system that will allow us to study contractual choice, we use our data to estimate the function coefficients (δ_1, δ_2, δ_3 and δ_4) of the irrigation services production function in equation 1. The four parameters describe the relationship between irrigation services and collective management, t, effective labor, L (which includes labor and the effort to supervise it) water use, W and the village's irrigation infrastructure, H. In our estimation, an irrigation service is measured as total water fee collected. We also use our data to create four input variables: collective management is measured as time spent on canal maintenance; labor is measured as total labor days input in proving irrigation services. We assume that the production technology is characterized by constant returns to scale (CRS), although we also, for robustness purposes, also estimate an unrestricted production function. The restricted and unrestricted production functions are both estimated with and without fixed effects at county levels to account for differences in local characteristics that might affect the provision of irrigation services.

The estimate of irrigation production function actually performed well (Table 1). We cannot reject either the hypothesis of CRS. The estimated function coefficients do not differ statistically between our model with and without fixed county effect. Because of this, although we ultimately use the estimated coefficients from the restricted production function (that is with CRS imposed) without fixed effects in our simulation analyses (Table 1, column 3), our ultimate comparative static results (which come out of the simulation analysis) are not sensitive to the exact functional form that we use. [1]

Using our estimates, we are able parameterize our model (Appendix B) mostly with parameters that are consistent with our data. For example, our baseline parameters for the production coefficients (rounding) are: $A = 3.6$; $\delta_1 = 0.271$; $\delta_2 = 0.244$; $\delta_3 = 0.388$; $\delta_4 = 0.097$; $\varepsilon = 0.52$. Interestingly, although we are examining a completely different production process than Eswaran and Kotwal (1985), the function coefficients are similar. We also set the opportunity cost parameters of the village leaders and managers, v=1 and u=0.8, and input prices, w=1, r=0.2, on the basis of our data; in our data the average daily wage of village leaders exceeds that of canal managers by about 20 percent and in our sample; water price per ton (r) calculated from the data is around 20 percent of wage of labors (w). Sensitivity analysis is performed throughout the analysis to ensure our choice of parameters are not driving the results.

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[1] Because of the form of the production function and set up of the problem, the *direction* of the changes of the choice of contract always move in the same direction in response to the shift of the exogenous factors for parameter values in the general range of our estimates.

In figure 1, if γ_1^c and γ_2^c are the critical values of γ_1 and γ_2, the point at which the village leader will choose to switch from a profit-sharing to a fixed-wage contract, or the point at which she would switch from a profit-sharing to fixed-payment contract, 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 all of the characteristics of the village's irrigation system, other village characteristics, the characteristics of the leader and the manager constant. The only thing that varies is the relative efficiency of the village leader (canal manager) being able to perform supervisory (collective) activities. The determination of these critical values can be found by simulating the model (solving the three problems of village leader and comparing the profit level 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 an increment of 0.01). The result of such an exercise is denoted by the solid lines in Figure 1. Since area of the whole contract space is 1, we can treat space spanned by a specific type of contract as its probability of being chosen. If a characteristic of the village's irrigation system were changed, it is possible that γ_1^c and γ_2^c would change.

Predictions

The basic results from Figure 1 can be used to gain some intuition about why the form of the contract between the village leader and canal manager varies across space. The relative efficiency of the village leader (canal 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 village leader also is willing and able to devote herself to supervisory activities, such as water allocation and fee collection, (that is the village leader has a relatively high value of γ_1), the village leader may choose to manage the village's canals by herself and at most only hire a canal manager at a fixed wage to carry out certain rudimentary irrigation tasks under her direct monitoring. If on the other hand, a canal manager's ability to organize collective activities, γ_2, is high, the village leader may prefer to lease out the canal to an individual manager for a fixed-payment contract. When the village leader (canal manager) have little hope of increasing their ability to supervise effort-intensive (organize collective) activities, the values of γ_1 and γ_2 are both low and leaders may choose an profit sharing institutional 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:

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

Even if ability of village leader (canal manager) to perform labor-intensive supervisory (collective) activities is constant (that is, γ_1 and γ_2 are constant), changes in other factors might lead to changes in γ_1^c and γ_2^c. Examining the associations between contract choice and the other factors also will help explain differences among villages in their choice of irrigation system management. In Figure 2, Panels A to C illustrate the results of three comparative static exercises.

The optimal managerial form depends on the relative importance of collective activities and supervision activities (Figure 2, Panel A). The nature of the canal system, to a great extent, determines the relative importance of these two activities. Better canals typically require less maintenance. For example, if most of the length of a canal system is lined (with cement) there is less need for the village leader to mobilize labor to clean the canals. In this case, collective activities are less important. As a result, we might observe that δ_1 decreases relative to δ_2. In such villages, since the village leader will not play an important role in managing canals, there may be a need for a motivated manager to operate the rest of the irrigation system. In contrast, the need to have a motivated, hard-working canal manager provide effort-intensive supervision is relatively more important. Under these circumstances, there is a greater propensity for the profit-maximizing village leader to move away from a fixed-wage contract into a fixed payment contract (Panel A). In summary:

Prediction 2: *The optimal contractual form in a village depends on the condition of irrigation infrastructure, especially those of canals. The better is the condition of canals, the less important is collective activities, and the more likely a fixed-payment contract* *will be selected by the leader.*

Given the condition of the canals (and relative strengths of village leaders and canal managers), we would expect there to be more water conflicts between households in villages in which water is extremely scarce. There will be a greater need for the village leader to resolve those conflicts and it is more likely that the village leader will choose a fixed-wage contract, since she has to be involved in one of the most critical activities in the process of producing irrigation services (Figure 2, Panel B). On the other hand, in villages without water shortages, water-related conflicts rarely happened. Moreover, since there is more scope for saving water it is more important to supervise water allocation carefully since the more water saved, the more profit could be made. In the notation of our model, when supervising activities are highly valued, the parameter ε increases, and we can summarize:

Prediction 3: *The optimal contractual form in a village depends on the conditions of its natural environment, such as endowments of water resources and land. As water resources become more abundant (or land more fragmented), the supervision of effort-intensive activities becomes more valuable and the village leader will be more likely to grant a fixed-payment contract to an individual canal manager.*

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 canal manager, the opportunity cost of forgoing the other jobs to take on the tasks of managing the village's canals (u) will increase (Figure 2, Panel C). In this case γ_1^c will decrease (or γ_2^c will increase) relative to that of a village in which it is more difficult for canal manager candidates to find other jobs. The change in relative values of the opportunity cost parameter of the canal manager versus the village leader will change the bargaining power of the canal manager; as u rises, the village leader will have to lower the fixed payment or share (required by the leader of the manager) to attract the canal manager to take fixed-payment or profit-sharing contract. As a result, under such circumstances, it would be less profitable for a leader to offer a fixed-payment or profit-sharing contract, and we can summarize this as follows:

Prediction 4: *The optimal contractual form in a village depends on the economic environment in the village. The wealthier a region 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 village leader and the canal manager, the conditions of the canal network's infrastructure, the relative scarcity of water, and the level of development within the local economy. 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. While such a model is intuitively appealing, in the next section the predictions are tested empirically, first using descriptive statistics and then 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 others to not.

Contractual Choices, Nature of Irrigation System and Characteristics of Village Leaders and Canal Managers

In the same way that Wang et al. (2003) found that water management reform was implemented in some villages but not others, the nature of incentives offered to water managers in our sample also varies across villages (Table 2, rows 1 and 2). Although there are substantial proportions of both profit-sharing and fixed-payment contracts (25 percent and 28 percent), in most villages, fixed-wage contracts are still the dominant form of canal management form (48 percent). If fixed wage contracts can be identified by non-reforming villages, then it can be seen that there are still many villages in our sample that have yet to reform. In the rest of the section, we try to answer why when water management reform has been shown to lead to water savings without much impact on production or rural incomes, many communities have not implemented it.

While puzzling, our descriptive data illustrate some of the differences between the villages that have different types of contracts. When we divide the sample into three parts, those villages with irrigations systems run under fixed-wage, fixed-payment and profit sharing systems, we find that villages vary systematically by some of the same variables that our theory predicts should influence contractual choice. For a number of different factors, we can show that when the canal manager is provided with partial or full income rights (that is, they are run under profit sharing or fixed payment contracts), these villages share certain features. For example, villages under fixed-payment contracts have a higher percentage of the length of their canal network that is lined (Table 2, row 3). This result is exactly what our theoretical model predicts. In villages where the canals are better lined, there is less need for the village leader to use his comparative advantage in organizing collective activities to mobilize labor to clean canals. Since his skills are less valuable, the village leader can lease out the canal and run the irrigation as a fixed-payment contract, since the canal manager is more efficient at supervising other activities. Using an alternative measure of the ease of maintenance (the amount of investment in the canal network since 1980), we find the same result: When the village is under fixed-wage contract, there seems to be more investment on canals (row 4).

A related finding also appears in our data and supports our theoretical predictions. In our sample villages we find that longer canals are more likely to be associated with fixed-wage contracts (Table 2, row 5). Without accounting for the ease of maintenance (that is, lining), a longer canal will require more maintenance and be within a village in which there are more water-related disputes. Because of the importance of being able to organize collective activities in such villages, leaders may have an advantage over canal managers and so they decide to run the irrigation system themselves in a large fraction of the villages.

Features of the environment surrounding canal systems, such as water scarcity and the degree of land fragmentation of the village's cultivated land, also are at least loosely correlated with the contractual forms chosen. For example, in villages with abundant water resources, the village leader is more likely to offer a fixed-payment contract (row 6). In contrast, when water is abundant, the village leader may choose a fixed-payment contract. These patterns are not surprising, however, as they are consistent with our theoretical predictions. When water is scarce, the village leader may have to be in charge since she is relatively adept at resolving the water-related conflicts that will invariably arise. When there is more water, it may be more feasible for an individual canal manager to run the irrigation system. Not only will there be less conflict, but there may also be more scope for water savings, a necessary condition to provide a canal manager with an incentive to save water.

Interestingly, our data also show that, in some villages, village leaders systematically appear to compromise in their choice between fixed-payment and fixed-wage contracts by choosing profit-sharing contracts. When the village's cultivated land is highly fragmented (measured either by number of plots per household or total number of plots in the village), we find there villages choose profit-sharing contracts more frequently (row 7 to 8). One explanation for this is found in our theory. When there are many plots, the irrigation system may not only have to be long and intricate (requiring a lot of collective activities), but farmers may be more demanding within a such a heterogeneous environment (requiring more supervisory activities). Hence, in such villages the skills of the village leader and canal manager are both important and only a profit-sharing contract can provide at least some incentives (although not full incentives) to both parties to carry out the activities in which they have a comparative advantage in.

The types of contracts also vary systematically with the characteristics of village leaders and canal managers. In our data we find that village leaders who choose to manage canals by themselves tend to be younger and more educated. On average these leaders have almost two more years of education than those village leaders who lease out the canal (row 11 to 12). Younger village leaders may have the energy and be less burdened with other activities (they have not had time to build village enterprises) and can devote more time to supervising effort-intensive activities simply by working for longer hours. Moreover, it could be that those with more education can perform multiple tasks—that is both collective and supervisory activities--more efficiently. In contrast, we find that it is the opposite story from the side of canal managers. Older and less educated individuals are the ones who sign fixed-payment contracts with village leaders. These characteristics may be proxies for their experience in water management inside the village and work opportunities outside the village (rows 13 and 14).

In the villages within our sample, we can also observe a congruence of the economic structure of the village and its type of canal management (Table 2). In villages with fixed-wage contracts, the share of non-farm income in the village's total income is almost twice that of villages with fixed-payments (30 percent versus 18 percent, row 15).

Villages also appear to favor fixed-wage contracts and have the village leader run the irrigation system when villages have greater access to off-farm jobs (either in local wage earning jobs in local firms, as migrants or in self-employed enterprises--row 16 to 18). When the opportunity cost of the canal manager is higher, he will require a lower payment to take on the management duties of the village's canal network. Since this would reduce the payment to the village leader, taking this into account, she is more likely to prefer a fixed-wage contract, ceteris paribus.

In summary, the data indicate a strong correlation between contractual form, the nature of the canal system and the environment within which the canal system operates. Characteristics of the village leader and canal manager, including their opportunity costs, also seem to vary systematically with contractual choice. From these findings, we can see that many descriptive statistics are consistent with the predictions derived from our theory. It is possible, however, that these simple correlations are not revealing the true underlying relationships, which could likely be complicated by intricate interactions among the variables of interest. To further explore these relationships, in the next section, we use multivariate analysis to help us more formally test our predictions.

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 test the theoretical predictions from the contractual choice model, a series of multinomial, limited dependent variable regressions are run using the data that are available for our sample canals. Our empirical framework allows us to answer the question: what factors in a particular locality induce the village leader to choose to offer the canal manager fixed-wage, profit-sharing, or fixed-payment contracts.

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

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

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

$$p_{ij} = \Pr[y_i = j] = \frac{\exp(\mathbf{X}'_i \beta_j)}{\sum_{l=1}^{3} \exp(\mathbf{X}'_i \beta_l)}, \quad j = 1, 2, 3.$$

where j is the index for alternatives and i is number of observations. We include in the ***X*** vector those factors we observed in the last section to test our predictions and discover the determinants of contractual form. Specifically, we use age and years of education as proxies for the relative ability of the village leaders and canal managers in order to test prediction 1; we use the percentage of the canal that is lined, investment per meter of the canal network and the overall length of the canal to indicate the condition of the canal so as to test prediction 2; we use two environmental factors, water availability (whether it is abundant or scarce) and land fragmentation (average number of plots per household), to test predictions 3; and, we use one measure of the relative opportunity costs of canal manger (percentage of non-farm income) to test prediction 4.

A potentially important drawback of the MNL model is the independence of irrelevant alternatives property. 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 error term is logistic (Hausman and McFadden, 1984). We carry out both Hausman test and Small-Hsiao test to test the null hypothesis of the independence of irrelevant alternatives. Results from both tests reject the null hypothesis. Therefore, there is no strong evidence that the probability of switching from one type of contractual form to another is independent of the third type of contract.

Controlling for the heterogeneity between counties is likely to be important in satisfactorily explaining the contractual choice of the village leaders, although it may create some statistical concerns. Wang et al. (2003) finds the policy efforts from upper level officials (including the county) are important explanatory factors of why some villages reform and others do not. Although we could add variables that measure county-level characteristics and their policy effort, this list invariably will be limited and leave a concern that the measured impacts of our explanatory variables might also proxy for other (omitted) variables. As a result, to control for the unobserved heterogeneity, we use a model with fixed effects at the county level. However, allowing for fixed effects in a nonlinear discrete choice model such as probit or logit will make it so that the estimated coefficients could suffer from an "incidental parameter problem" (Neyman and Scott, 1948; Lancaster, 2000). Because the number of parameters (county dummies) increases with the sample size, the maximum likelihood estimation becomes inconsistent. Greene (2002) finds that although the bias is persistent, it drops off rapidly as length of panel (the number of county dummies in this paper) increases to three or more. In our sample, since there are four counties, the bias from using fixed effects may not be a serious problem. To guard against the impact on our results that might come from using fixed effects with our multinomial estimator, in Appendix D we also report results of multinomial logit regressions without county dummies. Most signs of the coefficients do not vary among the estimators, although the magnitudes become somewhat larger when we include county dummies.

Since we are interested in the village leader's choice of one type of contract over another, we report in Table 3 the coefficients that represent the relative risk of choosing one alternative rather than another. Marginal effects on the choice probabilities dues to changes in explanatory regressors are reported in Appendix C.

Results

In general, our empirical estimations perform satisfactorily, especially given the fact that our sample is relatively small (Table 3). The goodness of fit measures, pseudo R^2, is around 0.5 for the multinomial logit equations with or without county dummies, which is sufficiently 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 with fixed-payment contracts while others run theirs with fixed-wage contracts. For example, our results are consistent with prediction 2 that states that contractual choices by the village leader depend on the characteristics of the canal network (Table 3). Having canals with more lining, which reduce the value of the skill in which the village leader has a comparative advantage, encourages the village leader to progressively move toward providing contracts with better incentives for the canal manager. The positive sign on the coefficient of the variable defined as average investment per meter of the canal demonstrates that as increasing investment improves the conditions of canals, the village leader has a greater propensity to switch from the traditional fixed-wage contract to the fixed-payment contract (row 2, column 2). On the other hand, the negative sign on the variable indicating the length of the canal indicates that longer canals, which ceteris paribus will require more maintenance, make the village leader more reluctant to provide the canal managers with incentives. In the villages with long canal networks, the village leader may be the best choice to run the canal system. Even though she forgoes the greater effort that the canal manager would exert in supervising water distribution, her ability to organize collective action appears to be even more valuable (row 3, column 5 and 6). [2]

The analysis also provides support for our prediction 3; the contractual choices of the village leader vary systematically with features of natural environment. The significant and increasingly larger coefficients (in absolute value terms) that appear when moving from profit-sharing to fixed-payment equations show that the village leader may find it optimal to offer the canal manager better incentives when water resources become more abundant (row 4). When land in the village is more highly fragmented, and there is a need for both better coordination and closer supervision, the village leader finds profit-sharing contracts more profitable (row 5).

Our estimated impacts of variables representing the economic environment of the village also are consistent with our theory (prediction 4). The negative sign on the coefficient of the percentage of non-farm income variable illustrates that when villagers have more access to non-farm activities, even if the village leader would like to provide the canal manager with full incentives (because the canal network might require a lot of supervisory activities), the village leader is more inclined to run the canal system under a fixed-wage contract (row 10). In such a village, the canal manager's opportunity cost is higher. The village leader would have to lower the fixed payment to induce the manager to take the contract. Apparently, in many cases the payment is so low that the village

[2] However, multivariate analysis also reveals our theoretical prediction might vary or reverse under certain circumstances. In contrast to our prediction, a canal with better lining is more likely under a fixed-wage or profit-sharing contract instead of fixed-payment contract (row 1, Table 3). The reason might be the village leader wants to have retain control of a good canal although she knows only offering a proportion of the profit will give canal managers less incentive to work harder. It could also be that lined canals reduce the need to supervise water allocations if such systems have better control values and gates that are easier to operate.

leader decides she would rather continue running the village's irrigation herself under a fixed-wage contract.

Multivariate analysis also provides support for our prediction 1; the optimal contractual choice depends on the relative abilities of the village leader and canal manager. Negative signs on both the age and education variables (those of the village leader) indicate that more capable village leaders are less likely to lease out canals on a fixed-payment basis or share profits with a canal manager (row 6 to 7). Older individuals, perhaps with more water management experience, are more likely to get involved in canal management (row 8). The education of the canal manager, however, demonstrates more support for prediction 4. If the opportunity cost of the canal manager rises with his years of education, our model predicts that, ceteris paribus, the village leader has a greater propensity to choose to perform all tasks by herself (because she would have to accept a lower payment to afford the more educated canal managers).

Conclusion

The main purpose of our paper is to explain the puzzling fact that in pursuing water management reform, village leaders have provided incentives to canal managers in some areas, but not in all. Our findings indicate that one of the reasons that not all village leaders provide strong incentives stems from the specific characteristics of the irrigation system. If the conditions of canals or other factors do not allow for profitable operation of the canal under the profit-sharing or fixed-payment contract, the village leader would not be motivated to lease out the canal to the canal manager. In addition, the nature of the village's resource and its economic environment as well as the characteristics of its leaders and the pool of possible canal managers will affect contract choice.

In other words, our findings 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 village 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 more broad water reform strategy. According to our results, water management reform has potential to work in some areas. Hence, they should be encouraged. However, in other areas they will not be appropriate. In such areas pushing water management reform will not only be difficult, but they may produce negative results if forced. Losing the village 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 (in some areas) and complementary policies in others) may be more successful in the long run.

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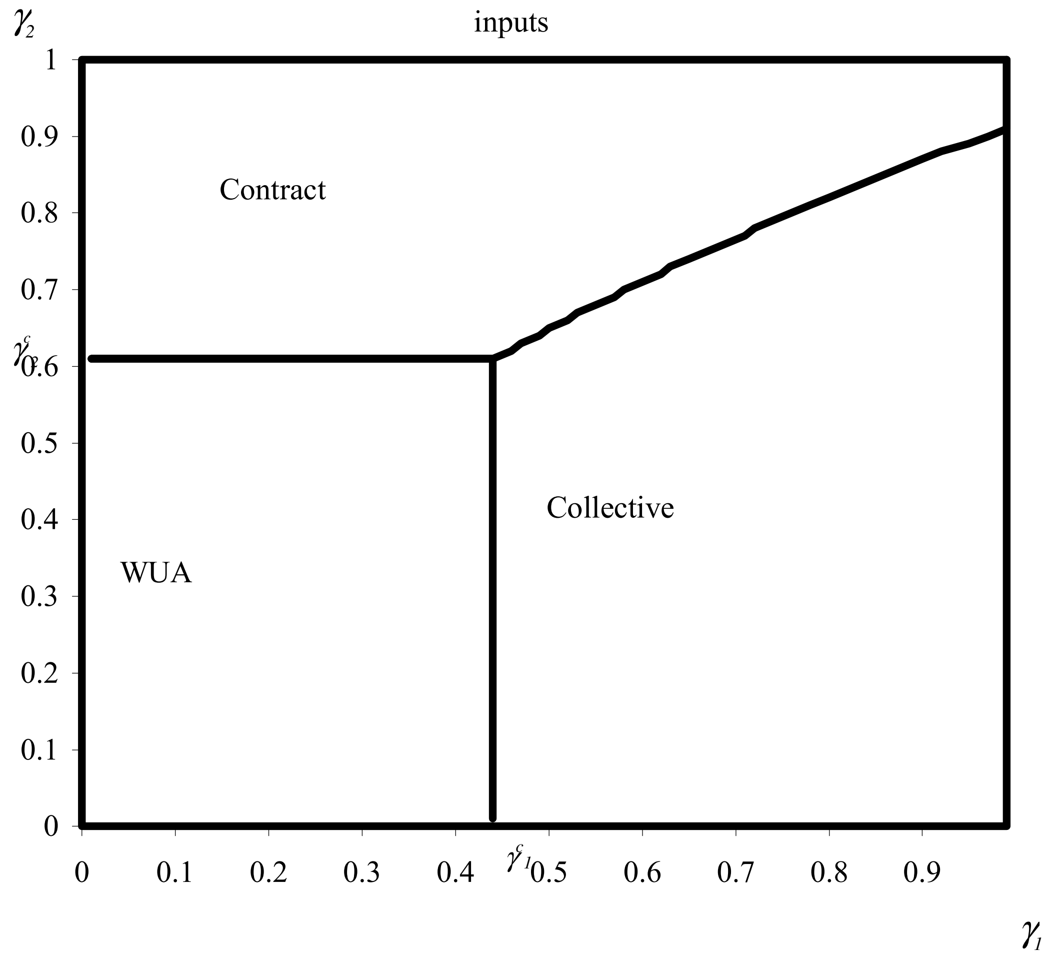
Table 1. Estimates of production function parameters for use in simulations

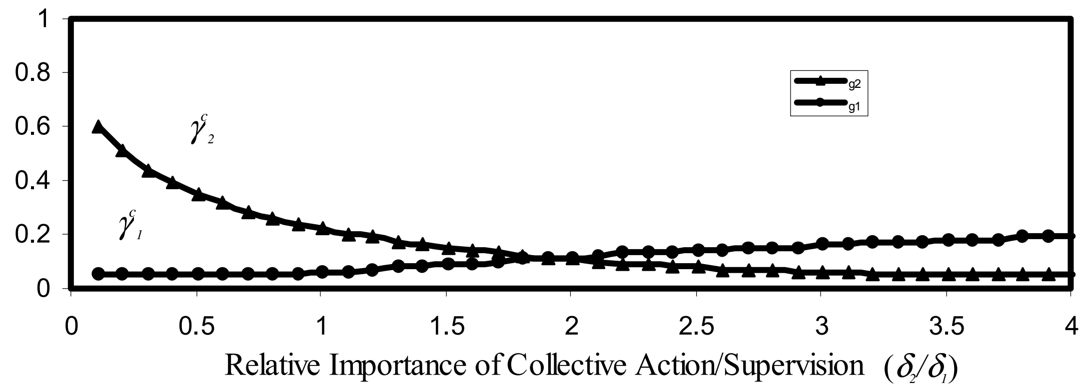
	Unrestricted Production function estimates		Restricted Production function estimates	
	Without fixed effect	With fixed effect at county level	Without fixed effect	With fixed effect at county level
Time spent on collective canal management (*t*)	-0.092	-0.050	0.271	0.300
	(1.25)	(0.61)	(3.43)***	(3.63)***
Time spent on supervision (*s*)	-0.043	-0.031	0.126	0.147
	(0.85)	(0.57)	(1.85)*	(2.20)**
Number of Labors used in canal manage (*L*)	0.017	0.019	0.118	0.104
	(0.64)	(0.65)	(3.44)***	(2.85)***
Total Usage of Water (*W*)	0.115	0.128	0.388	0.373
	(1.55)	(1.57)	(4.00)***	(3.66)***
Investment in Irrigation Infrastructure (*H*)	0.060	0.054	0.097	0.077
	(1.98)*	(1.71)*	(2.10)**	(1.70)*
Constant	9.515	9.137	2.280	3.187
	(7.97)***	(7.07)***	(2.50)**	(2.97)***
Observations	40	40	40	40
R-squared	0.22	0.20		
Number of county		5		5

Absolute value of t statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

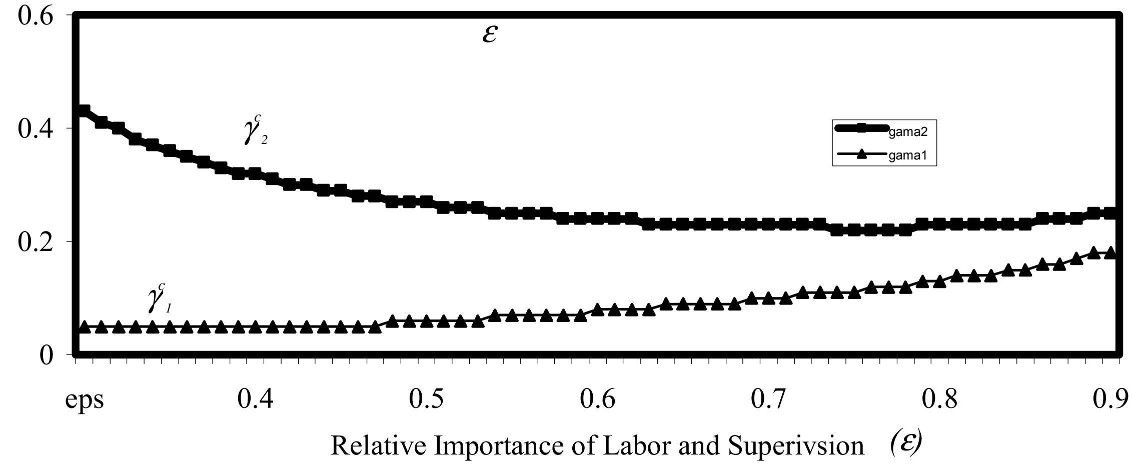
Figure 1. Optimal contratual forms under varying degrees of comparative advantage for village leader- and canal manager- supplied inputs



Panel A. Dependence of Critical Relative Efficiency Parameters on
Relative Importance of Collective/ Supervision Management



Panel B. Dependence of Critical Relative Efficiency Parameters on Relative
Importance of Labor and Superivsion



Panel C. Dependence of Critical Relative Efficiency Parameters on Relative
Opportunity Incomes of Village Leaders and Canal Managers

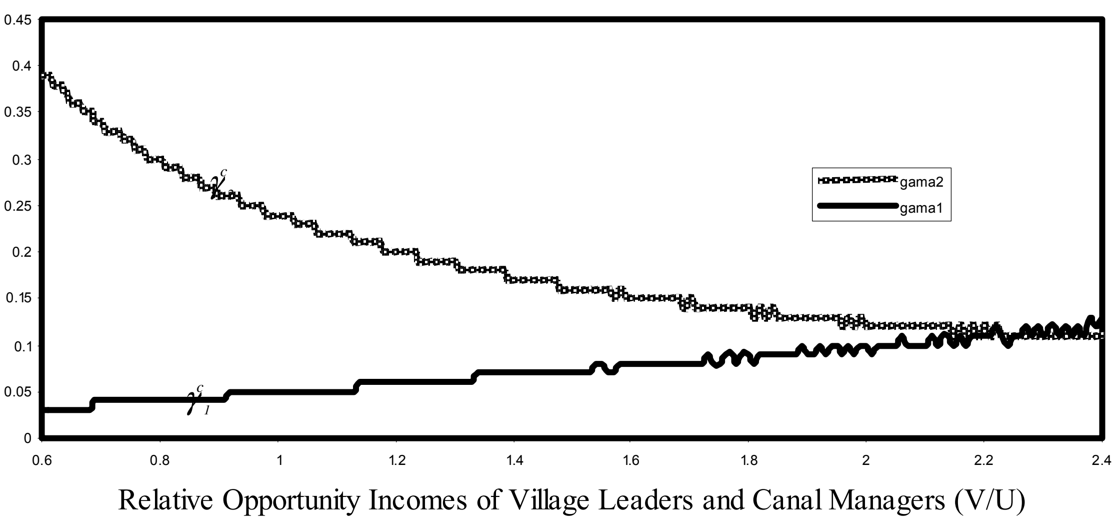


Table 2. Characteristics of Different Types of Contractual Forms

	Contractual Form	Fixed-wage	Profit Sharing	Fixed-payment
1	Number of observations	19	10	11
2	Percentage	(47)	(25)	(28)
	Characteristics of Canals			
3	Percentage of a canal that is lined (%)	67.23	63.94	71.36
4	Average investment per meter of canal (Yuan)	261.77	77.89	111.45
5	Length of a canal (m)	3851.74	2821.80	3178.09
	Water availability			
6	Degree of water availability (from 1 to 4)[a]	3.53	3.40	3.91
	Degree of Fragmentation			
7	Average number of plots per household	7.02	8.90	7.30
8	Total number of plots in the village	2322.42	2465.38	1650.14
	Demographic characteristics			
9	Total number of household in the village	376.79	340.10	360.18
10	Total population in the village	1556.53	1442.80	1464.36
	Human Capital Characteristics			
11	Years of age, village leader	49.97	51.60	50.14
12	Years of education, village leader	8.29	7.70	6.55
13	Years of age, canal Manger	43.58	45.80	46.55
14	Years of education, canal manger	8.95	7.10	6.91
	Economic structure			
15	Percentage of non-farm income (%)	30.09	23.30	18.00
16	Percentage of labors working in TVE (%)	1.07	0.17	0.30
17	Percentage of labors working outside village (%)	14.01	8.95	9.58
18	Percentage of labors with self-business (%)	9.31	7.04	4.53

a. Vary from 1 to 4 where 4 denotes water resource are most abundant.

Table 3. Multinomial Logit regressions explaining contractual choice by the village leader in Ningxia Province with county dummies

		(1)		(2)		(3)	
	Base category: Fixed-wage	Profit-sharing	Fixed-payment	Profit-sharing	Fixed-payment	Profit-sharing	Fixed-payment
1	Percentage of canal that is lined	0.033	-0.056	0.017	-0.037		
		(1.63)	(2.47)**	(1.02)	(2.07)**		
2	Average investment per meter	-0.027	0.004				
		(2.17)**	(2.57)**				
3	Length of canal					-0.001	-0.001
						(1.98)**	(1.44)
4	Degree of water availability [b]	-2.519	3.378	-1.753	2.598	-2.312	1.535
		(2.35)**	(3.61)***	(2.17)**	(2.90)***	(2.15)**	(1.23)
5	Average number of plot per Household	0.823	-0.488	0.153	-0.154	0.085	-0.029
		(2.11)**	(1.62)	(0.71)	(0.75)	(0.27)	(0.15)
6	Age of village leader	-0.187	-0.203	-0.121	-0.137	0.090	-0.008
		(1.42)	(2.18)**	(1.34)	(1.39)	(0.71)	(0.12)
7	Years of education, village leader	-0.113	-0.619	-0.022	-0.349	-0.128	-0.412
		(0.40)	(2.09)**	(0.10)	(1.36)	(0.50)	(1.20)
8	Age of canal manager	0.291	0.362	0.175	0.226	0.188	0.095
		(2.31)**	(2.47)**	(2.09)**	(2.04)**	(1.99)**	(1.24)
9	Years of education, canal manager	-1.103	-0.441	-0.627	-0.389	-0.528	-0.345
		(2.87)***	(1.68)*	(2.54)**	(1.58)	(2.09)**	(0.94)
10	Percentage of non-farm income	-0.085	-0.148	-0.069	-0.122	-0.043	-0.037
		(1.46)	(2.11)**	(1.59)	(1.86)*	(1.12)	(1.11)
	Observations	40		40		40	
	Pseudo R^2	0.517		0.447		0.456	

a. Since fixed-wage contract is the base group, coefficients imply how explanatory factors induce leaders to move away from (positive coefficient) or toward (negative coefficient).

b. Vary from 1 to 4 where 4 denotes water resource are most abundant.

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

Appendix A. Descriptive Statistics of Variables

Variable	Obs	Mean	Std. Dev	. Min	Max
Dummy for type of contracts [a]	40	1.8	0.85335	1	3
Age of village leader	40	50.425	5.10725	39	62.5
Years of education, village leader	40	7.6625	2.65153	2.5	15
Age of canal manager	40	44.95	6.40092	31	63
Years of education, canal manager	40	7.925	2.51547	2	12
Percentage of a canal that is lined (5)	40	67.5448	37.7934	5.26316	162.3411
Length of canals (m)	40	3409	1654.44	1000	7000
Average investment per meter of canals (yuan)	40	174.459	560.546	0	3583.767
Total investment on canals (yuan)	40	566413	1913058	0	1.22E+07
Degree of water availability [b]	40	3.6	0.74421	2	4
Average number of plots per household	40	7.56667	2.59713	2.25	12.25
Total number of plots in the village	40	2173.28	1372.87	176.25	5669.5
Total number of household in the village	40	363.05	131.47	135	700
Total population, person	40	1502.75	549.606	532	2860
Percentage of non-farm income (5)	40	25.0675	18.5834	0	80
Percentage of labors working in TVE (%)	40	0.63355	1.93153	0	11.32076
percentage of labors working outside village (%)	40	11.5243	11.6353	0	44.21053
Percentage of labors with self-business (%)	40	7.42722	7.0735	0	30.18868
Total revenue from operating irrigation system (yuan)	40	118987	157814	6060	883436
Total profit from operating irrigation system (yuan)	36	4207.91	26283.9	-43519	107700

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

b. Vary from 1 to 4 where 4 denotes water resource are most abundant.

Appendix B. Model of water managerial form choice

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

$$Q = \theta F(t, E, W, H) = \theta f(t, s, L, W, H; \varepsilon) \tag{1}$$

where *f* is assumed to be linearly homogeneous, increasing, and concave in its first four arguments. In (1), 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 a lot of rainfall, irrigation services would be easily provided. On the other hand, in a dry season, farmers would depend heavily on irrigation services provided. Other symbols are the same as defined in the paper.

The model is based on the assumption that the village leader and the canal manager each has one unit of the time that must be allocated between irrigation service provision and their alternative activities. The opportunity income of village leader is *v*, and that of canal 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 parameters, *v*, *u*, *w*, *r*, and *P* are all assumed to be exogenously determined, and the labor market is competitive.

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

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

$$s.t. \qquad 0 \le t_1 \le 1, 0 \le s_1 \le 1, 0 \le t_1 + s_1 \le 1. \tag{2}$$

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

where $\overline{Q}$ is amount of irrigation that must be provided to farmers.

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

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

$$s.t. \qquad 0 \le t_2 \le 1, 0 \le s_2 \le 1, 0 \le t_2 + s_2 \le 1. \tag{3}$$

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

$$R = \max\left\{0, \pi_2^{fp} - u\right\} \tag{4}$$

and village leader's income is:

$$\pi_1^{fp} = v + R \tag{5}$$

Under *profit-sharing contract*, the village leader and canal manager each provide one 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*:

$$\pi(t, s) = \max_{W, L} Pf(t, s, W, L, H) - rW - wL \tag{6}$$

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

$$S_2 = \alpha + \beta\pi \tag{7}$$

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

$$S_1 = -\alpha + (1-\beta)\pi \tag{8}$$

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

$$\max_{s_2} \beta\pi(t_1, s_2) + (1-s_2)u \qquad s.t. \quad 0 \le s_2 \le 1 \tag{9}$$

and:

$$\max_{t_1} (1-\beta)\pi(t_1, s_2) + (1-t_1)u \qquad s.t. \quad 0 \le t_1 \le 1 \tag{10}$$

Equations (10) and (11) will give the best response functions:

$$s_2 = \sigma(t_1;\beta), \qquad t_1 = \tau(s_2;\beta) \tag{11}$$

At a Nash equilibrium pair $[t_1^*(\beta), s_2^*(\beta)]$, which is shown in Eswaran and Kotwal (1985) to exist and be unique, Equation (9) and (10) are simultaneously satisfied.

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

$$\max_{\beta}\left\{-\alpha(\beta) + (1-\beta)\pi[t_1^*(\beta), s_2^*(\beta)] + [1-t_1^*(\beta)]v\right\} \tag{12}$$

The leader's expected income is thus:

$$\begin{aligned}\pi_1^{ps} &= -\alpha(\beta^*) + (1-\beta^*)\pi[t_1^*(\beta^*), s_2^*(\beta^*)] + [1-t_1^*(\beta^*)]v \\ &= \pi[t_1^*(\beta^*), s_2^*(\beta^*)] + [1-t_1^*(\beta^*)]v + [1-s_2^*(\beta^*)]u - u\end{aligned} \tag{13}$$

After solving each of these maximization problems (Equation (2), (5) and (13)) ex ante, the criteria used by village leader to choose canal managerial form is simple: compare expected income under all three contract forms, Equation (2), (5) and (13), and choose the contract that maximize his/her expected income.

Appendix C. Marginal Effect of Explanatory regressors on probability of choosing one type of contract of Models in Table 3 (dF/dX)

	Model (1)			Model (2)			Model (3)		
Explanatory regressors	Fixed-Wage	Profit-sharing	Fixed-Payment	Fixed-Wage	Profit-sharing	Fixed-Payment	Fixed-Wage	Profit-sharing	Fixed-Payment
Percentage of canal that is lined (%)	0.0000	0.0003	-0.0003	-0.0024	0.0025	-0.0001			
Investment per meter of canals (yuan)	0.0002	-0.0003	0.0000						
Length of the Canal							0.0002	-0.0002	0.0000
Availability of water	0.0033	-0.0235	0.0201	0.2479	-0.2556	0.0077	0.3408	-0.3533	0.0125
Average number of plot per household	-0.0047	0.0076	-0.0029	-0.0218	0.0222	-0.0005	-0.0127	0.0130	-0.0003
Age of village leader	0.0029	-0.0017	-0.0012	0.0178	-0.0175	-0.0003	-0.0135	0.0136	-0.0002
Years of education, village leader	0.0047	-0.0010	-0.0037	0.0040	-0.0031	-0.0009	0.0214	-0.0190	-0.0025
Age of canal manager	-0.0048	0.0027	0.0021	-0.0257	0.0252	0.0005	-0.0289	0.0285	0.0004
Years of education, canal manager	0.0127	-0.0102	-0.0025	0.0915	-0.0908	-0.0007	0.0814	-0.0799	-0.0016
Percentage of non-farm income	0.0017	-0.0008	-0.0009	0.0102	-0.0099	-0.0003	0.0067	-0.0065	-0.0002

Note: All marginal effects are evaluated at mean of explanatory regressors. z-statistic is not reported here for brevity.

Appendix D. Multinomial Logit regressions explaining contractual choice by the village leader in Ningxia Province without county dummies

	(1)		(2)		(3)	
Base category: Fixed-wage	Profit-sharing	Fixed-payment	Profit-sharing	Fixed-payment	Profit-sharing	Fixed-payment
Percentage of canal that is lined	0.001	-0.020	-0.001	-0.018		
	(0.07)	(1.31)	(0.09)	(1.28)		
Average investment per meter	-0.004	0.002				
	(0.96)	(1.96)*				
Length of canal					-0.001	-0.000
					(2.30)**	(0.99)
Degree of water availability [b]	0.427	2.202	0.469	2.040	-0.638	1.457
	(0.57)	(1.91)*	(0.65)	(1.84)*	(0.64)	(1.39)
Average number of plot per Household	0.415	0.007	0.363	0.029	0.386	0.067
	(1.21)	(0.03)	(1.17)	(0.13)	(1.27)	(0.35)
Age of village leader	0.083	-0.037	0.086	-0.046	0.195	-0.020
	(0.67)	(0.44)	(0.74)	(0.54)	(1.14)	(0.24)
Years of education, village leader	0.095	-0.137	0.107	-0.106	0.050	-0.263
	(0.46)	(0.66)	(0.52)	(0.51)	(0.24)	(1.19)
Age of canal manager	0.103	0.149	0.095	0.130	0.193	0.107
	(1.25)	(1.65)*	(1.16)	(1.41)	(2.00)**	(1.50)
Years of education, canal manager	-0.224	-0.337	-0.213	-0.352	-0.237	-0.315
	(1.03)	(1.27)	(1.01)	(1.34)	(0.95)	(1.16)
Percentage of non-farm income	-0.020	-0.080	-0.024	-0.078	-0.038	-0.048
	(0.50)	(1.76)*	(0.66)	(1.80)*	(1.09)	(1.40)
Constant	-12.391	-7.043	-12.162	-5.342	-13.206	-3.586
	(1.07)	(0.88)	(1.16)	(0.68)	(1.15)	(0.48)
Observations	40		40		40	
Pseudo R^2	0.263		0.245		0.335	

a. Since fixed-wage contract is the base group, coefficients imply how explanatory factors induce leaders to move away from (positive coefficient) or toward (negative coefficient).

b. Vary from 1 to 4 where 4 denotes water resource are most abundant.

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