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Water User Associations and the Evolution and Determinants of Management Reform: A Representative Look at Northern China

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Increasing demand for China's limited water resources (across China, but mostly in northern China) from rapidly growing industry, urban populations and agriculture implies potentially dire consequences for the sustainability of water use and drastic changes in cultivation patterns (Zhang, 2001). Problems in the water sector also have significant implications for China's future trade position in key crops and may affect the income of the farming sector (Huang et al., 1999).

Despite such grave consequences, China's government has responded relatively slowly in trying to systematically address growing water shortages (Wang et al., 2007). In fact, there are many laws and formal regulations specifying how communities should use and manage their water. Unfortunately, few of these measures have been implemented.

That is not to say that there is no response to growing scarcity. In fact, it appears that a number of institutions – created by the actions of farmers, groups of farmers and community leaders – have arisen in the wake of rising scarcity (Chen, 2002; Fang, 2000). Some, like the Water User Associations (WUAs) in certain World Bank's project areas, have been shown to be effective in raising the efficiency of irrigation, increasing incomes and doing so while helping a village's poor farmers (World Bank Project Reports). But beyond a relatively few internationally-funded sites, relatively little is known about WUAs and other forms of water management institutions. In particular, little is known about exactly what it is about where WUAs have emerged; in what types of communitieis have they emerged; and whether or not they help alleviate China's water crisis. The few studies that have been done on some of the water institutions that have arisen in recent years have demonstrated mixed results. Indeed, Wang et al. (2005b) found that WUAs—the institutions that have been so successful in Bank project areas—were *not* generally successful. Instead canal contracting (to individuals), a form of institutional reform that is prevalent in many different contexts of China's reforms, was more successful. The problem is, however, is that these results form Wang and coauthors are from only four irrigation districts in two provinces and do not pretend to be national representative.

This lack of understanding and the absence of empirical evaluations by researchers are somewhat surprising given the amount of effort the government is putting into this effort. In fact, understanding why institutional changes emerge (and work) in some places and not in others is even more important now that there are efforts by the Ministry of Water Resources to begin to push institutional change and management reform across wide areas of China (World Bank Policy Brief).

In order to overcome a.) the general absence of information of water management reform; b.) increase our understanding of water institutions, including WUAs specifically; and c.) try to identify what it exactly is that leads to the creation of WUAs in one place but not in another, in this paper we are pursuing the following objectives:

(1) *document* the existing water management institutional forms throughout China, their evolution over time and across provinces;
(2) *describe* the actors and their roles and other governance issues in WUAs and compare them to traditional collectively managed irrigation systems and other types of reform-oriented irrigation institutions (especially contracting);
(3) *analyze the determinants* of the emergence of these institutions throughout China in order to understand the role of scarcity of water resources; the size of the community's irrigation system, policy and other village characteristics in their emergence.

On the basis of the results found in the pursuit of objectives (1) to (3), another one of the uses of this paper is that it will provide the background paper for a follow-on, survey-based, more *intensive* study of why some institutional forms (specifically, water user associations) have succeeded in certain areas (specifically World Bank project areas that have promoted WUAs and surrounding areas in which WUAs have been promoted by the government) and not in others. It should be noted that because this is a paper based on our *extensive* data set, it will not be able to answer the full complement of questions in which we are ultimately interested. For example, we will not try to understand the impacts of WUAs in this paper. We also can only examine finer details of the institutional components of WUAs in a small subset of our villages which are not national representative. These limitations will be addressed in the follow-on paper (part 2 of this project).

To meet these objectives, the rest of the paper is organized as follows. First, we will discuss the dilemma of China's surface water policy. Because of the nature of China's farming practices—since almost all of China's agriculture is based smallholders who farm small, dispersed plots, it is hard to use water pricing policy in surface water areas. This makes irrigation management reform important and it is with this motivation that we launch our study of WUAs and other water management reforms, their governance and determinants. In the second section we discuss the data. In the following two sections, the spread of WUAs, their governance and their other characteristics are examined—first descriptively and then with multivariate analysis. The final section concludes.

Farm Structure, Surface Water Irrigation and Missing Incentives to Save Water

So why is it that if there is a water crisis in parts of China that farmers in those regions do not always save water? It has been shown that the adoption of water saving technology is very low in China—including in many areas in which farmers and local leaders believe are water scarce (Blanke et al., 2007). For many types of water saving technologies, such as plastic sheeting, sprinkler systems, drought resistant varieties, drip irrigation, etc., the average adoption rates in the typical northern China community are only around 10 to 15 percent.

Because of the unwillingness of households to seek ways to save water, in many parts of China (especially in northern China) ground and surface water sources are being

depleted and current water-use levels are not sustainable with the current water supply systems (Lohmar et al., 2002). It also is a fact that agricultural users will not be given priority for any additional sources of water that become available (World Bank, 1993). Indeed, while it is the stated goal of China's leaders to increase irrigated area, they also explicitly acknowledge that this expansion will occur without any additional water allocations to agricultural users. Thus, using water more efficiently is the only method to increase irrigated area and its effectiveness without increasing total agricultural water demand in North China.

Incentives for Water Saving and Water Pricing Policy

The reasons for the absence of interest in adopting water saving practices are found in the nature of the incentives faced by China's farming community. Until the 1970s water was considered abundant in most parts of China and was not even priced for agricultural users so there was no incentive for users to save water.[1] Collectives had de facto rights over the water in their communities—either that underground or in nearby lakes, rivers, or canals. Facing low or free water prices, farmers naturally used as much water as they wanted. Even today, most farmers "save" water only when their deliveries are curtailed and not because the price is too high or because they are given other incentives to do so.

Shortly after the agricultural reforms that began in 1978, the central government encouraged the adoption of volumetric surface-water pricing. The reliance on prices to help limit water use did not begin all at once in all locations but instead was allowed to diffuse gradually as experience was gathered. Water pricing was also restricted by regional price bureaus which often did not allow prices to rise any where near their marginal value product (Huang et al., 2006). Because of the differences in the pace of implementation of surface water pricing schemes, the price structure exhibits substantial variation across the country. Because of the slow pace generally, the value of the marginal product of water in most parts of China is still far above the cost that the farmer is actually paying in most regions.

China's leaders currently are embarking on a new round of water pricing reform to better match water prices with the benefits of using the water (Wang et al., 2006). For several reasons, however, the focus is on the domestic and industrial users (Lohmar et al., 2003). Whether water prices will be raised for agricultural users is still hotly debated. There is widespread agreement that water prices are too low in China. Water prices will certainly increase for domestic and industrial users, but it is still unclear if the same set of policies can be implemented for agricultural users. Many policymakers believe that raising water prices for agricultural users is the only effective way to get farmers to implement sound water-saving measures (Blanke et al., 2007). Others claim, however, that raising water prices for farmers will only further burden poor farmers facing low agricultural prices and in many cases high input prices (Rosegrant and Cai, 2002). The

[1] Farmers generally had to volunteer labor, however, to construct and maintain water storage and delivery infrastructure during this period.

extra pricing burden of a "water tax" would directly counter another important policy goal in China: raising rural incomes and reversing a rising rural-urban income gap.

Instead of getting farmers to pay for water on a volumetric basis, it is increasingly common to measure water for volumetric pricing at the point of entry from the irrigation district into the village. According to our data water can be volumetrically measured (at greater and less great degrees of accuracy) as it enters the village in more than 80% of northern China's villages. Once it has flowed into the village's canal system, water fees charged to individual households are usually a prorated amount of the total fee paid at the point of delivery (plus additional costs to cover the collection effort of the water officers and other water managers). The prorated amount is generally based on the size of the household's irrigated land endowment.[2]

Under this type of a surface-water pricing system, farmers have little incentive to reduce their water use since they will be charged for it anyway. Indeed, there is an incentive to use more than one's share of the water, the classic free-rider problem, especially in large irrigation groups that are more difficult to monitor. Upstream users have more opportunities to "free-ride," using more water than they pay for, to the detriment of downstream users. When this happens, downstream users that pay the same water fee per hectare as upstream users actually pay more per unit of water because their deliveries fall as the upstream farmers apply more than their share. Interviews produced repeated stories of how upstream users, after opening channels to deliver water to their fields, have no incentive to close them. In extreme cases, users at the end of the lateral canals do not get any water and refuse to pay water fees.

Not only is most surface water priced in a way that does not take volume into account, but price collection practices are such that most farmers in China currently do not even know exactly how much or when they are paying for water. Many IDs use a system that in essence "bills the village" for the amount of water they provide to the village. The funds that pay for this fee is sometimes transferred to the ID through the administrative bureaucracy (e.g., through a township/county agent or representative of the ID). Traditionally, since the accountant must also settle accounts with farmers on several other transactions, including local taxes, education fees, and collectively provided services (such as running water and agricultural services such as plowing or spraying), water fees sometimes are lumped together in a single bill for all services and taxes. The clearing of accounts is sometimes done only once or twice a year. In many cases the water that a farmer pays for had actually been applied as many as 6 months earlier. In 2000 the authors ran a survey of more than 1,200 farmers across China and discovered that only a fraction of them (between 20 to 30 percent) could tell enumerators the price they paid for surface water—either per unit or land area or per cubic meter.

In summary, then, the fragmented and small-scale nature of China's farms will pose a significant problem if the government becomes committed to raising prices of

[2] There is some true volumetric pricing for individual farmers, but this is relatively rare in surface systems and is restricted to farmers near the head of main canals who have intake pipes directly from the main canal into their fields (groundwater deliveries, however, are often priced volumetrically).

surfaced water and charging for water on a per unit basis to encourage water savings in agriculture—especially in surface water systems. In the absence of transaction costs, a system of volumetric pricing for individual farms would be preferable to the current system. The high transaction costs of measuring water intake at hundreds of millions of small parcels throughout China and collecting fees on a farm-by-farm basis, however, would probably not be the most cost-effective solution. Moreover, joint accounting practices instituted to minimize the transaction costs involved in fee collection have been shown further divorced the farmers' production decisions from the value and amount of water that they apply. Research to understand how large these problems are, and what the optimal group size might be for charging for water, is important for water prices to effectively encourage water savings at the farm level.

Although farmers do not always know the exact fees they pay for water, in cases that we have observed in which water prices are high and water shortages serious, farmers do have a qualitative understanding that the more water their irrigation group uses, the higher its fees will be. In some areas, water fees clearly are not trivial for farmers. A survey of farmers conducted in two villages in Hubei Province concludes that irrigation fees (for surface water and groundwater, including pumping costs) account for about 10% of the farmers' total production costs and 18% of cash outlays. And these fees are in a central province that is water abundant relative to the more northern provinces. In Hebei province water can account for up to 20 percent of total production costs. With agricultural commodities in China so competitive (profit margins are often under 10 percent), the way that water is used and priced to the farmer could have a large impact on the profitability of farming and the income of farming households. In other words, farmers understand water is expensive and would like to find ways to allocate more optimal amounts to their crops, if they can find a way to do so.

Irrigation management reform

With the failure and infeasibility of several of their policy options, such as water saving technology promotion and water pricing at the household level, leaders in recent years have begun to consider community-level water management reform as a key part of their strategy to combat China's water problems since they believe water in agriculture is being used inefficiently. Despite water shortages, users in all sectors of the economy—but especially those in agriculture, by far the nation's largest consumer of water—do not efficiently use the water that they are allocated. One study, for example, estimated that due to the poor management of the nation's canal network, only 50 percent of waters from primary canals are actually delivered to the field (Xu, 2001). Local irrigation managers and farmers also do not efficiently use the water that reaches the village's fields, wasting between 20 to 30 percent of their water. Hence, overall, only about 40 percent of water in China's surface water system that is allocated to agricultural production is actually used by farmers on their crops. Others have estimated even greater inefficiencies (Fang, 2000). In response, it has been proposed that local leaders reform the institutions that manage water in China's communities (Nian, 2001; Reidinger, 2002).

Despite the resolve of the current leadership in China to push water management

reform, there is considerable debate about its appropriateness. International evidence shows that water management and its institutional arrangements are important measures for dealing with water shortages (World Bank, 1993; IWMI and FAO, 1995). Since the 1980s many developing countries have begun to transfer irrigation management responsibilities from the government to farmer organizations or other private entities in order to mitigate the financial burden of water projects and to improve the efficiency of water use (Vermillion, 1997). Theoretically, local water management reform is supposed to rely on increased participation by farmers and provide better incentives for managers to improve access to water and increase the efficiency of the system.

Unfortunately, the records of a number of attempts to implement local water management reforms have not lived up to expectations; there are many cases internationally of efforts that have failed or generated negative influences (Easter and Hearne, 1993; Vermillion, 1997; Groenfeldt and Svendsen, 2000). Collective action (getting participation right) and the failure of getting the incentives right may be among the most important reasons that the water management reforms have failed.

In fact, since the 1990s China's policy makers have actively promoted water management reform, and like similar attempts outside China, the record seems to be mixed although most evaluations are only based on anecdotes or case studies (Nian, 2001; Huang, 2001). There are reports, such as in the World Bank project areas, that water management reform has had a dramatic impact on water use efficiency and farmer income. Even in those areas in which management reform has been well-designed, however, effective implementation of the reform has been difficult (Ma, 2001). Visits to the field can easily uncover cases in which local water management changes were implemented and failed.

Although there are many similarities between international experiences and those of China, even in this early phase of reform the nation's water management reform strategy has taken on some unique characteristics—which also vary from place to place. Above all, water officials have emphasized the role of incentives in water management reform in many areas. In many of the new reform efforts, water managers are provided with monetary rewards if they can meet certain targets, such as achieving water savings. In other areas effort has been placed in encouraging participation by farmers in the management of the local irrigation system. Some have tried both incentives and participation.

While the prominence given to encouraging participation is mostly based on international experience, the attention given to incentives may be unique (especially in the case of water management reform in developing countries). The use of incentives, however, is not new in the context of China's overall economic reform effort. Reformers frequently have relied on incentives to induce agents to exert more effort, allocate resources more efficiently and enter into new economic activities (Naughton, 1995). The household responsibility system primarily gave incentives to farmers in crop production (Lin, 1992). The fiscal reforms gave local leaders incentives to begin township and village enterprises (Walder, 1995). The grain reforms gave grain bureau personal the

incentive to commercialize commodity trading (Rozelle et al., 2000). Clearly, high level water officials are hoping a similar set of reforms can improve the performance of China's water management. Of course, perhaps because of its relative uniqueness, when a system of incentives to managers is used for water management, it is possible that there are unforeseen consequences (i.e., it is possible that it could have effects on productivity and/or income distribution)

In the rest of the paper we will seek to understand the extent to which water management reform have emerged, especially how Water User Associations have been extended across China. We also are interested in the nature of the governance in the areas in which they have been promoted. Finally, we are interested in understanding why WUAs and other water management reform emerged in some areas and not in others and if they appear to be an effective tool in addressing China's growing water crisis. To do so the next section introduces the data used in the study. In the following sections we then exam the spread of WUAs and their characteristics and determinants descriptively and by using multivariate analysis.

Data

Broad-scale, published data on China's surface water users and the institutions that govern them is extremely limited. The analysis presented here is based mainly on our own primary data collected as part of two recent surveys specifically designed to examine irrigation practices and agricultural water management. The first survey, the *China Water Institutions and Management* survey (CWIM), was conducted in September 2004. Enumerators conducted surveys of community leaders, surface water irrigation managers and households in 56 villages in Ningxia and Henan provinces. The 2004 CWIM survey built on a similar survey conducted in 2001 and so the authors had access to panel data. This survey is described in more detail in Appendix A.

The study team also conducted a second survey, the *North China Water Resource Survey* (NCWRS), in January 2005. This survey of village leaders from regionally representative villages in Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi provinces used an extended version of the community level village instrument of the CWIM survey—but did not directly interview farmers or canal managers. Using a stratified random sampling strategy for the purpose of generating a sample representative of northern China, counties in each province were sorted into one of four water scarcity categories: very scarce, somewhat scarce, normal and mountain/desert. Two townships within each county and four villages within each township were also randomly selected. In total, the data collection team visited 6 provinces, 60 counties, 126 townships and 448 villages. The survey collected data on most variables for two years, 2004 and 1995. The NCWRS data forms the core of the data for this study and will be supplemented by the CWIM data when we seek to understand the implementation of surface water management reforms from the farm household's point of view. We also refer to results from the CWIM survey (reported in Wang et al. 2005b) when we discuss the possible

impacts of the adoption of water management reform, including WUAs, in water use, crop output and rural incomes.

The scopes of these surveys were quite broad. Each of the survey instruments included more than 10 sections, including sections focusing on the nature of rural China's surface water resources and groundwater problems. Several sections examined government policies and regulations, such as the extent of the effort of the government to promote water management reform, in general, and WUAs, in particular. Other sections examined issues of water saving technology and the infrastructure of the village water sector. Additional information on the survey and methodology can be found in Wang et al., (2007) and Blanke et al., (2007).

The key section of the survey for this paper came from the surface water management block of the survey form. In each village the enumerator asked the respondent about how the surface water system was managed in their community. They were given four choices (defined below in the next section): collective management, Water User Associations, contracting and other. Others included, most typically, villages that had *mixed systems* (that is, for example, part of their village's canal system was managed by a contractor and part by a WUA). A series of questions was asked about the governance each type of water management form as well as the incentives faced by managers. In the CWIM survey, which enumerated farmers, questions about the extent of the participation by farmers were asked.

Reform and the Evolution of Water Management

Based on our field surveys (and as analyzed in Wang et al., 2005b), after upper-level officials began implementing the reforms, surface water is managed in three general ways. If the village leadership through the village committee directly takes responsibility for water allocation, canal operation and maintenance (O&M) and fee collection, the village's irrigation system is said to be run by *collective management*, the system that essentially has allocated water in most of China's villages during the People's Republic period. A *WUA* is theoretically a farmer-based, participatory organization that is set up to manage the village's irrigation water. In WUAs a member-elected board is supposed to be assigned the control rights over the village's water. *Contracting* is a system in which the village leadership establishes a contract with an individual to manage the village's canal network.

Trends in Water Management Reform, 1995 to 2004

According to our data, between 1995 and 2004 China water management reforms have gradually established WUAs and contracting in place of collective management in northern China, however, tracking these changes is complicated by the changing nature of China's water resources (Table 1).[3] In 1995 out of the 448 villages that we visited (see

[3] See Appendix Tables 1 and 2 for a complete accounting of the sample villages and nature of their irrigation systems in 1995 and 2004.

the description of the sample in previous section), 235 had surface water irrigation (column 1, row 9). During the survey the enumerators found that of the 235 villages with surface irrigation in 1995, 30 of them (13 percent of villages with surface water irrigation) had stopped using surface water by 2004 (row 8). However, between 1995 and 2004 17 villages (7 percent) were provided with surface water for the first time (row 10).

When examining the villages that used surface water in both 1995 and 2004 (a total of 205 villages—235 minus 30), there is a clear tendency for villages to be reforming their water management structure (Table 1, row 1). Of the 181 villages that were being managed under the traditional collective management style, only 143 were still managed in this way in 2004 (columns 1 and 2). In other words, in 38 villages (181 minus 143) some form of water management reform was implemented.

The reform efforts during the 1995-2004 time period was split almost exactly between shifts to WUAs and contracting (Table 1, row 1, column 3). Villagers in 14 villages choose to create WUAs (column 4). Villagers in 18 villages shifted into contracting. There were also six villages (2+2+1+1) that reformed only part of their village's surface water system or chose a mix of WUAs and contracting (columns 5 to 8).

While the trend in northern China's village is clearly reform-oriented, it is interesting to note that in villages that had already reformed by 1995, there is some evidence that villagers are continuing to experiment with different institutional forms and are not afraid of going back to collective management (Table 1, rows 1 to 7). For example, of the eight villages that had created WUAs to manage their surface water systems in 1995, three of them had either discontinued or partially discontinued the experiment by 2004 (row 2). Two of the 11 villages that chose contracting systems in 1995 decided to either fully or partially go back to traditional collective management by 2004 (row 3). On the one hand these shifts into and back out of WUAs and contracting may mean that water management reform is not universally successful. Another interpretation for national leaders worried about whether or not surface water management reform is suitable to China's villages, however, is that even if effort is made to actively promote WUAs and contracting, villages are not locked permanently into the new management forms.

Interestingly, the emergence of water management reform is not closely tied with the creation of a new irrigation system (Table 1, bottom row). In the 17 villages which were the beneficiaries of new surface water irrigation systems between 1995 and 2004, 14 of them (or 82 percent) chose to be managed under the traditional collective management system. Only three – one WUA; one contracting; and one with a joint collectively managed/WUA structure – chose to implement a reform-like management system. This percentage of reformed management villages (among newly irrigated villages—17%) is lower than the overall average (27%).

So how should one interpret the record of water management reforms between 1995 and 2004 in northern China? In the aggregate, our data show that the changes were

significant (Figure 1).[4] The share of collective management declined from 90 percent in 1995 to 73 percent in 2004. Across our sample, WUAs and contracting have developed at about the same pace. By 2004 10 percent of villages managed their surface water through WUAs and 13 percent under contracting. When counting the mixed systems (which rose from 2 to 4 percent between 1995 and 2004), by 2004 27 percent of villages in northern China had been affected by water management reform (10+13+4). While WUAs and contracting are still far from the most common forms of water management, if we assume that half of China's 800,000 villages are in our study area, this means that more than 100,000 villages have reformed, at least nominally, the way they manage water.

While there has been a general shift from collective management to WUAs and contracting during the past 5 years, water management reform still varies across the six sample provinces in 1995 and 2004 (Appendix Tables 3 and 4). For example, the use of traditional collective management between 1995 and 2004 has fallen in 5 sample province—Inner Mongolia, Ningxia, Liaoning, Shanxi and Henan provinces. In Shaanxi and Hebei, however, the use of collective management actually rose. But even among the five provinces that experienced net positive reform, there were striking differences. In our sample villages in Inner Mongolia the use of traditional collective management fell from 89 percent in 1995 to 44 percent in 2004. In Ningxia collective management fell from 78 percent in 1995 to 31 percent in 2004. The other three provinces (Liaoning, Shanxi and Henan) reformed significantly less. The share of villages under collective management fell by only 5 to 10 percent in these three provinces.

Beyond the differences across the villages regarding their decision to reform or not, the direction of reform also varied among provinces (Appendix Tables 3 and 4). Most poignantly, villages in Inner Mongolia, one of the two provinces with the most actively reforming sample villages, almost all (13 of 17 reforming sample villages) decided to manage their surface water systems through WUAs instead of contracting. In contrast, villages in the other active reform province, Ningxia, chose mostly contracting. There also were differences in the choice of the direction of reform in the other provinces. For example, all of the villages that had chosen to reform by 2004 in Shanxi and Hebei chose contracting. However, 5 of the 6 reforming villages in Shaanxi chose to manage their surface water through WUAs instead of contracting.

Based on our field survey, although some of the differences in water management among the IDs may be due to the characteristics of local villages and local water management initiatives (explored later in this paper), the dramatic differences among provinces suggest that government policy may be playing an important role. For example, in 2000, in order to promote water management reform, Ningxia provincial water officials issued several documents that encouraged localities to proceed with water management reform (Wang, 2002). Regional water officials exerted considerable effort to promote water management reform in a number of experimental areas. In Hebei (a non-reforming province), when we approached provincial officials about water management

[4] Since our data are national representitative and since we know the population weights of each sample province, sampling stata, counties, towns and villages, we are able to produce point estimates for northern China (an areas that covers China north of the Yangtze River and excludes Xinjiang, Qinghai and Gansu.

reform in Hebei's surface water systems, no one knew anything about it. The sharp shift away from collective management (in certain provinces) is consistent with an interpretation that these policy measures were effective in pushing (or at least relaxed the constraints that were holding back) reform.[5]

The differences among the villages in our sample and variations in the way that different regions implemented the reforms (i.e., some moved to contracting while others shifted to WUAs), however, show that the nature of the reforms are far from universal. In fact, this is what would be expected in China. These regional differences are most likely a characteristic of reform in China, a nation that often allows local governments considerable room in making their own decisions on the exact form and timing of institutional changes (Jin et al., 2000).

Governing WUAs

The shift in China's water management institutions demonstrates that the nation's communities at least in part are following policy directives that are being developed and issued from upper-level governments. In this section we examine how local leaders govern traditional and reformed water management institutions, especially WUAs. We also examine the difference between governance in WUAs and contracting (the two competing types of reform institutions).

According to our data, when villages say that their water systems are being run under a certain institutional form, our data show that there appears to be fairly major shifts of responsibilities (Table 2). When a village claims its surface water system is being managed under the traditional collective management system, nearly all water management activities are carried out by the village leadership (rows 1 to 5). Canal maintenance, coordination of water delivery and water fee collection is fully (100%) the responsibility of the village. In a small share of villages (22 percent) farmers themselves must operate the sluice gates according to the schedule set by village leaders. Respondents told us during the survey that 33 percent of villages with collectively managed irrigation systems also depended on township or ID officials if there was a dispute that required resolution.

Likewise, when a WUA is set up most of the responsibilities for managing the village's canal system is carried out by the WUA (Table 2, rows 6 to 10). In villages with WUAs our respondents told us that the WUA board is fully (100%) responsible for the operation of sluice gates, water fee collection and conflict resolution. Interestingly in half of the villages with WUAs that we interviewed, the WUA had responsibilities for canal maintenance, but in the other half the village leadership—apart from the WUA—kept

[5] In our field work and during the survey we spent considerable time discussing with officials about that way that they pushed water management reforms. They told us that, in fact, they used a variety of ways, including issuing policy promotion documents, organizing meetings with local leaders to discuss the reforms, and talking to village leaders in more informal ways. In this way, we believe that the reforms have relaxed constraints that had kept village leaders from reforming irrigation management. We believe the main function of the action of the officials have been to send a signal to village leader that the previous prohibitions against contracting out the village's irrigation system were being relaxed.

responsibility. This was done, at least in several villages (according to our interviews), because canal maintenance was carried out by small group leaders and the small group members, while the WUA is a village-wide organization. WUAs also split responsibility with village leaders and farmers for coordination of water delivery.

In contrast, the organization of water management activities is more complicated when contracting is used (Table 3, rows 11 to 15). In contracting villages, the village council fully (and jointly with the contractor) helps the contractor carry out all of the different activities. Certainly in part this is because contractors may lack the ability to carry out certain activities (e.g., canal maintenance). It also may be that they are unable to act as a disinterested party in the execution of other activities (e.g., dispute resolution).

Incentives

Another major difference in governance among water management institutions concerns the incentives faced by the managers if the irrigation system in the village performed well and earned a profit. In our analysis we assume that village leaders are the managers of traditional collectively managed irrigation systems. The chair of the association (or board members) is the manager of the WUAs. And, of course, the contractor himself/herself is the manager in contracting villages.

Under these assumptions the differences in the incentives faced by managers clearly vary across institutional form and over time (Table 3). For example, in none of our villages (in either 1995 or 2004) that were run as collectively managed systems were village leaders paid a bonus or given any part of the residual revenues once all expenses were paid.

Leaders of WUAs were provided with more incentives that were rising somewhat over time. Specifically, leaders in 14 percent of villages with WUAs in 1995 and in 32 percent of villages in 2004 financially benefited if the irrigation system made money at the end of the cropping year. Even by 2004, however, WUA managers in less than one-third of villages faced incentives of any kind.

In contrast, the incentives faced by contractors rose fast and reached a high fraction of villages by 2004. Although only 27 percent of contracting villages offered managers financial incentives in 1995, the percentage reached 76 percent in 2004. Clearly, the nature of incentives distinguishes contracting significantly from collective management and WUAs.[6]

[6] It should be noted, however, that the existence of financial incentives for managers is considered a controversial feature of contracting among some officials and academics. The problem is that it is possible that in pursuit of his/her own profits, the manager of an irrigation system will cut back on services that are demanded by farmers (and which may be a routine part of the services provided in villagers with collectively managed irrigation systems or WUAs). Because of these potential conflicts, in the agreements between villages and contractors, there are many stipulations about what is required and what can and can not be done. Perhaps because villages are so small, monitoring is fairly good and effective and there have not been many troubles reported in the sample villages. Anecdotes and stories told by officials, however, suggest that in some villages there have been conflicts been contractors and villagers which have been caused by the differences in objectives between a profit-oriented manager and a set of farmers that want inexpensive, reliable and timely service.

Practice and Theory: Participation in WUAs

So far, we have only reported the results of the survey results from the NCWRS. Although this is a comprehensive survey, it also relies on the opinion of only one or two respondents (usually the village leader and a representative farmer/canal manager).whose opinions are being recorded on a single survey form. In such a survey it is impossible to check the validity of some answers because of the lack of an alternative source of information. In the CWIM survey, however, we asked multiple stakeholders (village leaders; well owners; canal managers and farmers) separate sets of questions in an environment where the answer of each respondent was confidential from all others. Because of this we were better able to assess villages in which the practice of reformed irrigation management systems varies from theory.[7]

In fact, according to our data, especially in the case of WUAs in our sample, practice and theory vary sharply. In our survey we attempted to cover several major dimensions of participation. In particular, our definition of participation includes three parts: how farmers participated in the process of the establishment of reform process (e.g., the setting up of the WUA); the selection of the managers; and whether or not farmers were invited to attend regular business meetings. These three aspects on decision making almost cover all the major activities of water management institutions (their creation; the selection of the leader; and input into day to day business procedures).

Despite the important role that farmers play in water management in some parts of the world, according to our data, participation is not part of either China's traditional, collectively-run water management or contracting. Traditionally, the implementation of many government services in China is carried out from the top down with little consultation with or participation of farmers (Zhang et al., 2002). Although collectively-managed services, such as those provided by collectively-run water organizations, in theory are supposed to be determined by the entire collective, in fact, village leaders have managed their villages in a large part based on the authority that they have derived from higher-level officials. In our sample villages we find that farmers participate little (and mostly not at all) in collectively-run water management organizations. Similarly, by definition (and according to our survey results), contracting involves transferring control and income rights to an individual and involves almost no participation of farm households.

In contrast, the reforms that led to the creation of WUAs explicitly attempt to encourage farmer participation. However, practice often varies from theory. In the CWIM survey areas farmers have little voice in deciding the establishment of WUAs or appointing the management team of their community's irrigation system. For example, at least in the early stages of the development of WUAs (the only stage of the organizations that we are observing since this type of management is so new in our sample villages),

[7] The drawback of this part of the data, however, is that the sample was smaller and not nationally representative. All villages and towns were randomly selected (as were repondents within villages), but the coverage does not let us create point estimates of a regional or national practice or event.

our data show that, on average, only about 12.5 percent of WUAs involve farmers in the decision on their establishment. In fact, most farmers (70 percent) that are in villages in which the local irrigation system is being nominally managed by WUAs did not even know that they were part of a WUA.

Farmers also are seldom encouraged to participate in other parts of water management. Based on our random sample, *none* of the WUA governing board members actually is elected by farmers. Only 25 percent of WUAs allow farmers to participate in the process of selecting managers. As a result, in most cases (70 percent of the WUAs), the governing board of the WUA is the village leadership itself. In a minority share of the cases (30 percent of the WUAs), village leaders appointed a chair or manager to carry out the day-to-day duties of the WUAs. In many of these WUAs, however, the managers actually have close ties to the village leadership (for example, the manager frequently is a former village leader or a close relative of a current one). Moreover, although 80 percent of WUAs hold regular meetings, farmers are invited to participate only in 25 percent of them.

Compared with collective management and contracting, however, WUAs are more accountable to farmers. As discussed above, we assume that a relatively high degree of transparency at least in part reflects a relatively high degree of accountability. According to the field survey, we found that the degree of transparency for WUAs is higher than other management forms. In fact, all WUAs have some degree of transparency. Nearly 40 percent of WUAs shared all three types of information about the irrigation system with farmers (in other words, the WUA told farmers about the way water fees are generated; the volume of water that was actually delivered by the ID to the village; and the actual area that was irrigated). About 50 percent of WUAs shared two of the three types of information.

Incentives for Farmers

Somewhat ironically, since one of the main goals of water management reform is to provide farmers with better irrigation services, the design of the water management reforms placed little emphasis on the incentives for farmers. In many villages, at most, the water management reforms mandated that water fees paid by farmers should be reduced. However, the reduction in the water fees in most villages was quite modest. On average, water fees were reduced by only about 9 percent.[8]

Why are WUAs in some areas but not in others?

From the previous sections, it is clear that although there is a general trend that encouraging the reform of surface water management in northern China that reform is happening in some places and not in others. When reform is happening, in some villages

[8] This reduction in water fee was part of the initial arrangement between the contracting parties. The reformers, expecting a fairly large reduction in water use, wanted to make sure that farmers received at least some benefit (even though the reform was not supposed to affect their cropping incomes). This benefit was given to the farmers by reducing their water fees.

WUAs are chosen and contracting in chosen in others. In this section we seek to understand why. In other words we will examine the determinants of the choice of water management reform. We try to understand if it is the characteristics of the water resources, characteristics of canal infrastructure, policy or some other characteristics of the village or its leaders that differentiate villages that reform and those that do not. To do so, we first look at descriptive statistics and then carry out a multivariate determinants analysis.

Descriptive analysis

The descriptive statistics from our data demonstrate that the nature of a village's water resources is an important determinant of reform (Table 4, rows 1 to 3). Interestingly, however, it is not villages with the most severe water problems that are reforming. Indeed, according to our data, in collectively managed villages, there were more years during a specific 3-year time period (1993 to 1995—a time before we measured if there was reform) that there were shortages of water severe enough to have a significant negative effect on yields than in WUAs (0.92 versus 0.45—row 1, columns 1 and 2). In other words on average WUA villages reported there was only 0.45 years of water shortages across the three year period, while there were 0.95 years in collectively managed villages. The difference was statistically significant. Although the differences were not statistically significant, when asked in another way, it was found that water was also less scarce in WUA villages (row 2). In contrast, WUAs (and contracting) appeared in villages in which there was both surface and groundwater available in the village (that is, in villages in which it was possible to use surface and groundwater conjunctively) more frequently than in villages with collective management (row 3).

These findings (that reform occurs in areas with relatively better water resources) are important because they suggest that although water management reform is being pushed in part by policy makers as a solution to China's water crisis, WUAs and contracting are not being used in the most water short places. Although we do not know why, it may be a matter of feasibility of implementation. If water is too scarce, it could be that there is no scope for water savings which means that there is no contractor who is willing to take the contract (since no water savings would mean a lower income).

Although WUAs and contracting occur in areas with better groundwater resources, the descriptive data suggest that the same is not true when examining the quality of the infrastructure or the complexity (or at least size) of the irrigation infrastructure (Table 4, rows 4 and 5). The point estimates of our data show that when a large share of the canals is lined with concrete, there is a greater likelihood of having a collectively managed system. Specifically, when a village is collectively managed, on average, 22 percent of the canal system is lined. In WUA villages it is only 13 percent and is even lower (4.5 percent) in contracting villages. However, when the canal system itself is longer, there is a greater likelihood to find WUAs (14 kms) and contracting (30 kms) than collectively managed systems (6.7 kms). Hence, village leaders appear to be more willing to contract out or turn the irrigation system over to a WUA when the canal system is poorer quality and more complex (or at least longer). From the contracting and WUA point of view, it may be that in such an irrigation system there is more scope for improvement, since it is

possible that there was more waste during the period in which it was collectively managed.

As found in previous analyses by the authors on privatization of groundwater (Wang et al., 2005a), water saving technology adoption (Blanke et al., 2007) and other water reforms, policy appears to play an important role in encouraging water management reform (Table 4, row 6). In 77 percent of WUA villages and in 67 percent of contracting villages, provincial officials or ID personnel carried out extension campaigns to encourage water management reforms. In contrast, extension efforts for water management reform were only carried out in 25 percent of villages which did not reform and remained collectively managed. The differences in the descriptive statistics were significant.

There are other factors that appear to be associated with the adoption of WUAs. For example, villages which were richer (and significantly so), those with more migration and those with more self employed business (and significantly so) tended to adopt WUAs. WUA villages also tended to have leaders that were older and villagers that were better educated (at least compared to collectively managed villages). While it is not clear why, these descriptive numbers are consistent with the idea that it is not until a village is relatively better off and has its members more active in off farm sector that they begin to look for more effective ways to manage water. Alternatively, it may be that villagers in such communities are more open to change.

Multivariate analysis

In this section we conduct two separate empirical exercises. First, we estimate a logit model that seeks to answer the question, what are the determinants of reform. The dependent variable will be a dummy variable that is equal to one if the village has adopted either a WUA or contracting form of water management. The reform dummy variable will be explained by the variables examined in the descriptive analysis, including measures of the nature of water resources, the characteristics of the canal, policy and other variables measuring cropping patterns, socio-economic characteristics of the village, characteristics of village leader, village demography and locational factors. Because the dependent variable is a limited dependent variable (either 1 or 0), we choose to use a logit estimator. The model for the first exercise is:

(1) Reform_dummy = a0 + a1*Nature of water resources + a2*Canal characteristics + a3*Policy + a4*Cropping patterns + a5*Socio-economic characteristics + a6*Village leader characteristics + a7*Village demography + a8*Location dummies + e.

The second empirical exercise uses the same structure as equation (1) except the dependent variable is a dummy that is yes if the village adopted WUA and no otherwise. The model for the second exercise is:

(2) WUA_dummy = a0 + a1*Nature of water resources + a2*Canal characteristics + a3*Policy + a4*Cropping patterns + a5*Socio-economic characteristics + a6*Village leader characteristics + a7*Village demography + a8*Location dummies + e.

When we estimate equations (1) and (2) we do so in two ways—with and without provincial fixed effects.

Results

Results from Equation 1: Determinants of Water Management Reform: In fact, the multivariate analysis generates results similar to those found when analyzing the descriptive statistics. For example, when looking at the results of equation (1) we find that, ceteris paribus, villages that were relatively water abundant were those that reformed (or adopted non-collective forms of irrigation management—Table 5). Specifically, during the early 1990s (the time before our data), if a village suffered more years without enough water in their canals, the tendency was to *not reform* (row 1, columns 1 and 2). Also, when villages have conjunctive water resources in 1995 (which might be interpreted as having relatively more abundant resources, ceteris paribus), reform is more likely in 2004 (row 3). Clearly, if policy makers believe water management reform is going to help solve China's water crises, something additional is going to need to be done. Although water management reforms are spreading, our results demonstrate that they are going into areas with better water resources instead of those areas that are in crisis.

Likewise, reflecting the results in the descriptive statistics, villages appear to be reforming their water management when they have relatively poor infrastructure, but larger (and more complex?) systems. Although the coefficient is not significant, the point estimate of coefficient (which has a negative sign) of the canal lining variable means that those villages with less canal lining will reform more (row 4). The coefficient on the canal length variable is statistically significant from zero (row 5). The positive sign means that villages with longer canal systems have a greater propensity to reform. These findings are, in fact, consistent with Huang et al. (2006) which finds that WUAs and contracting are more likely to be chosen in villages with more complex canal systems. The idea is that in such systems managing the canal system is a labor intensive / management intensive system and it requires a manager with a great deal of motivation (which incentives or a participatory body could generate).

In addition, the policy dummy is positive, large in magnitude and highly significant (row 6). Importantly, the coefficient remains about the same magnitude and level of significance when provincial fixed effects are added (row 6, column 1 versus column 2). This means that at least a good deal of the policy effect is subprovincial. In other words, there is enough heterogeneity within provinces, that when WUAs and contracting are pushed in some villages, but not in others, there is a different rate of response within the province.

Few of the other control variables are of interest. While the coefficient on the income variable is positive, it is insignificant. Only the level of education of villagers in a village is significant. One explanation could be that villages with higher levels of education may be more willing to reform—because they are more flexible or because they might think WUA and/or contracting could provide them benefits of some sort and they are better able to judge this. Education could also be correlated with many other factors.

Results from Equation 2: Determinants of WUAs: The results of the determinants of WUAs (results of equations 2 in Table 6) are strikingly similar to the determinants of water management reform, in general (Table 5, as reported above). The signs, magnitudes and levels of significance for many of the main sets of variables are the similar. Like in the case of water management reform, in general, villages that had relatively more water available in the early 1990s and those with conjunctive water resources were more likely to shift into WUAs. Likewise, those villages with greater lengths of canals also were more likely to choose to create WUAs. Policy also played a positive role in promoting WUAs.

The results then are again consistent with the idea that extension efforts are needed to promote WUAs. However, not all villages in which extension efforts are exerted end up following the suggestions of officials. For policy efforts, such as water management reform, villages tend to have a lot of choice. Our results show that WUAs have emerged, like water management reform generally, in villages with relatively more water resources and in villages with larger irrigation systems. It is possible that in these villages there is room for new institutional forms to matter. If water is too scarce, for some reason, new water management forms are not making inroads. It could be that leaders and/or farmers in these villages are afraid to change in fear of making the current water crisis even worse (that might happen in the case of experimenting with a new managerial form). It could also be that there is no obvious benefit of change in areas in which water resources are so scarce and irrigation systems are relatively small so leaders and/or farmers are reluctant to bear the costs of trying out the reforms, including WUAs.

There is one set of coefficients in the determinants of WUA regressions (equation 2) in Table 6 that differentiate these results from those of equation 1. The positive and significant signs on the coefficients of the income per capita variable and the age and level of education of the party secretary variables suggest that WUAs have emerged in villages that were relatively well off with leaders that have more experience and higher levels of human capital. WUAs are either easier for such villages to organize or may be in greater demand in such villages.

Multinomial Logit Model—Robustness Check. We also include a third empirical exercise in the Appendix Table 5. In this third model, we estimate a multinomial logit model. A multinomial logit model estimates the effectiveness of a series of factors (the same variables on the RHS of equations 1 and 2) in explaining the simultaneously choice of the three types of managerial forms (collective management, WUAs, contracting). Using collective management as the base category, we find that the

results are consistent with both the descriptive results and the results of logit estimates in Tables 5 and 6.

Conclusions

In this paper we have sought to understand the reform of China's surface water management systems and its effect on water use, output, income and poverty. Research results show that between 1995 and 2004, collective water management has been replaced by WUAs and contracting in many locations. According to our survey data, by 2004 more than one-quarter of villages in northern China had reformed their water management institutions. Given several plausible assumptions, this means that more than 100,000 villages in northern China are managing their water in non-traditional ways. It is for this reason that it is important to understand more about them.

Our results demonstrate that when management reform is instituted in a village, at least nominally, there is a shift of responsibility from the traditional collective leadership to either the WUA governing board or contractor. Interestingly, our results find that different institutional forms have emerged in different provinces. The data also demonstrate that all reform institutions are not alike. While contractors face better incentives for earning money by good performance, WUAs managers have fewer incentives. WUAs have closer ties to the original village leadership. And, in practice, there is little participation by farmers—at least in the subset of villages from which we have data from farmers.

While we have not examined impacts in this paper (they will be examined in the part II of the report), in previous work these difference between WUAs and contracting are shown to matter. Indeed, one of the main features of China's water management reforms, the provision of incentives to water managers, appears to have succeeded in achieving large water savings while having only a small or no effect on agricultural production or rural incomes. Our findings demonstrate that in villages that provided water managers with strong incentives water use fell sharply. The incentives also must have improved the efficiency of the irrigation systems since the output of major crops, such as rice and maize, did not fall, and rural incomes and poverty remained statistically unchanged. If these results are true for our more extensive sample, since contractors had better incentives than WUAs, the form of the institutional reform may matter.

Because of this and broader concern, we also tried to explain why it is in some regions there are collective management, in other regions WUAs and in other regions contractors. We find that, in fact, reform is not going on in the most water scarce parts of China. Combined with our previous work (in Wang et al., 2005b) which showed that successful implementation of reforms did lead to water savings, at the best water management reform will keep these relatively water abundant regions from falling into crises relatively more gradually. However, it also means that as the reforms are being implemented now that they will solve the water problems in the water scarce areas.

Although we do not know why for certain, the results are consistent with an interpretation that under the current policy environment (in which water management reforms are based mainly on extension efforts), there are not enough incentives for water management reforms to be introduced into more water scarce areas. When water is relatively abundant and the canal network in a village is relatively large, there is scope for water savings and it is in these areas that village choose to reform. If it is determined that water management reform will also save water in communities in which water is relatively scarce (an outstanding research questions), then our results suggest that to successfully promote water management reform will take more effort at persuading and perhaps will require the investment of financial resources to make it more attractive.

Overall, we believe that our findings support the conclusion that the government should continue to support water management reform. But, more research is needed. Officials that want the reforms to succeed should make an effort to ensure that more emphasis be put on the effective implementation. We need to know, however, why the reforms are implemented effectively in one place, but not another. We also need to know the nature of the tradeoffs in relatively water scarce areas when the reforms are adopted. There is also a need (as we will begin to do in the next part of the research) to understand why WUAs (contracting) works in some villages and not in others and how they affect farmer welfare.

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Appendix A. Description of CWIM data set

In order to meet the study's objectives, we designed three separate survey instruments, — one for farmers, one for canal managers and one for village leaders. During our survey, three types of water management institutions were identified: collective management, Water User Associations (WUAs) and contracting. In our village and canal management questionnaires we recorded the share of canals within the village that is controlled by each management type for each of three years (1990, 1995 and 2001). In addition, enumerators also asked about how managers were compensated. When managers have rights to the earnings of the water management activities (that is, to the value of the water saved by water management reform), we say that they face strong incentives (or *with incentives*). If the incomes from their water management duties are not connected to water savings, they are said to be *without incentives*.

The CWIM survey also collected information that we use to develop several measures of the effects of water management reform—water use, production and income. In order to get relatively accurate measures of water use, which in surface water systems is typically difficult to elicit, we adopted the strategy to ask all of those that were involved in the irrigation scheme: farmers, water managers and village leaders. We asked about crop water use in a number of different ways: on a per irrigation basis, the number of irrigations per crop (information that was also asked of the farmerss), the number of hours per irrigation, the average depth of the water, etc. With this information, and information from the household), we were able to combine the various measures into a single measure on which we develop our final estimates of water use (see Appendix A).

We also systematically collected information on both income and crop production by plot and by crop for all cropping seasons during the year 2001. Income is an estimate of each household's full net income and includes all major sources of income of the household, including that from cropping, livestock, off farm wage labor, earnings from the family's business enterprise and other miscellaneous sources. As is standard in the household economics literature, we value all home production that is used for a household's own consumption at its market price. If the household did not buy or sell a product that it consumed itself, we use the average price from village to value the good. With information on income, we were able to construct a measure of poverty status by comparing household per capita income (dividing total household income by the number of family members, which include the household head, the household head's spouse and all individuals that lived in the household for at least three months per year) with the national poverty line (625 yuan per capita per year in 2001).

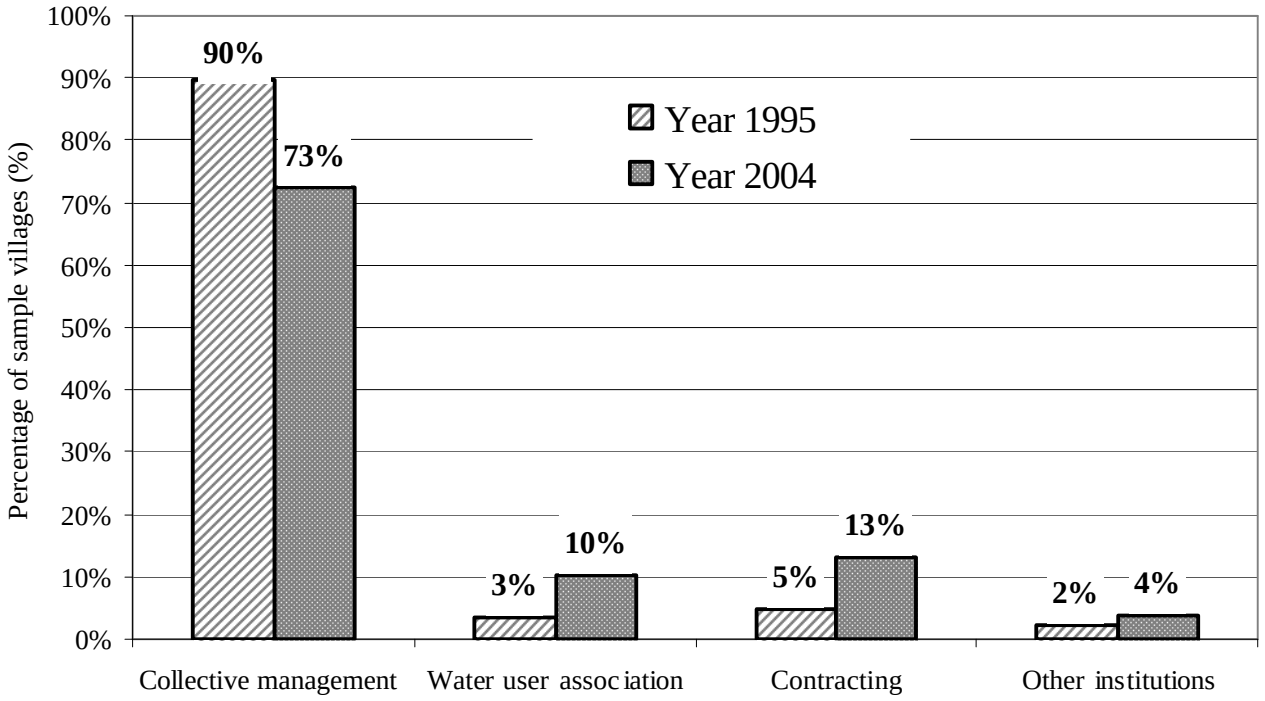

Figure 1. Changes in water management institutions from 1995 to 2004

Note: Other institutions includes the four types of mixed institutions: 1) water user association combined with collective management; 2) water user association combined with contracting; 3) contracting combined with collective management; 4) water user association, contracting and collective management

Source of Data: 2004 NCWRS and 2001-2004 CWIM Panel

Table 1. Transition matrix of changes in the forms of surface water management in northern China between 1995 and 2004.

Forms of surface water management in 1995	Number of sample villages	Water management institution in 2004						
		Collective management	Water user association (WUA)	Contracting	WUA and collective management	WUA and contracting	Contracting and collective management	WUA, contracting and collective management
Collective management	181	143	14	18	2	2	1	1
Water user associations	8	2	5		1			
Contracting	11	1		9			1	
WUAs and collective Management	1		1					
WUAs and contracting	1		1					
Contracting and collective management	2	1		1				
WUAs, contracting and collective management	1		1					
Villages that shut down SW irrigation between 1995 and 2004 [a]	30							
Total villages with SW irrigation in 1995	235	--	--	--	--	--	--	--
Villages with new SW irrigation created between 1995 and 2004 [b]	17	14	1	1	1			

Source of Data: 2004 NCWRS and 2001-2004 CWIM Panel

Table 2. Division of responsibilities for water management activities under different water management institutional forms in northern China sample villages, 2004.

Water management institution	Water management activity	% of sample villages in which a water management activity is carried out by:						
		Village Council	Water user association	Contractor	Water user association and village council	Water user association and contractor	Contractor and village council	Others [a]
Collective Management (n=161)	Canal maintenance	100						
	Operation of sluice gates	78						22
	Coordination of water delivery	100						
	Water fee collection	100						
	Conflict resolution	67						33
Water user Association (n=23)	Canal maintenance	50	50					
	Operation of sluice gates		100					
	Coordination of water delivery	25	50					25
	Water fee collection		100					
	Conflict resolution		100					
Contracting (n=29)	Canal maintenance	35		25			35	5
	Operation of sluice gates			90			5	5
	Coordination of water delivery	10		75			5	10
	Water fee collection	10		80			10	
	Conflict resolution			50			35	15

[a] Others include farmers, irrigation district and township government.

Source of data: CWIM-Ningxia province

Table 3. Incentives faced by canal managers in northern China sample villages, 1995 and 2004.

	Percentage of sample villages in which canal managers have been provided with incentives [a] (%)	
	2004	1995
Collective Management	0	0
Water user association	32	14
Contracting	73	27

[a] Canal managers are contractors in villages that have contracting. Elected board members (and/or the chair of the association) of the WUAs are the canal managers in villages that have WUAs. The manager of the system in a collective managed village is the village leader and/or the party secretary. If a canal manager is provided with earning incentives, it means he/she can claim all or part of the profits (or revenues after paying out expenses) from the operation of a canal. Usually a canal manager is either paid in a percentage of the water fee he/she collects or a certain percentage of residual profit from the operation of a canal.

Source of data: 2004 NCWRS

Table 4. Characteristics of water resources, canals, village leaders and villages under different water managerial forms in northern China sample villages.

	Collective management	Water user association	Contracting	Other institutions a
Number of sample villages b	111	22	24	7
Characteristics of water resources in the village				
Water availability (Number of years that there was not enough water in canals between 1993 and 1995)	0.92	0.45**	0.73	0.64
	(1.24) c	(0.80)	(1.07)	(1.18)
Village water scarcity indicator variable (1= water is scarce in the village in 1995, 0=otherwise)	0.1	0.05	0.04	0
	(0.30)	(0.21)	(0.20)	0.00
Conjunctive use (Percentage of land that is conjunctively irrigated by surface water and groundwater in 1995, %)	8.97	12.09	14.38	3.14
	(25.13)	(27.15)	(33.73)	(7.47)
Characteristics of canals in the village				
Canal lining (Percentage of the total length of tertiary canals that is lined in 2004, %)	22.1	13.3	4.56*	10.8
	(51.17)	(25.45)	(3.17)	(18.55)
Canal length (Total length of tertiary canals in the village in 2004, Km)	6.76	14.25***	30.22***	8.6
	(10.68)	(13.82)	(65.32)	(8.71)
Policy Dummy (1=government promoted water user association or contracting and 0=otherwise)	0.25	0.77***	0.67***	0.86***
	(0.44)	(0.43)	(0.48)	(0.38)
Cropping pattern Share of sown area in rice in 1995 (%)	21.69	17.36	12.92*	16.84
	(29.12)	(29.28)	(19.30)	(22.44)
Socioeconomic characteristics of villages				
Income per capita in 1995 (Yuan, in log form)	7.04	7.39**	7.09	7.34
	(0.67)	(0.37)	(0.38)	(0.50)
Percentage of migrants (%, share of village labor force that out migrated in 1995)	8.75	11.83	10.36	12.29
	(11.08)	(17.17)	(13.53)	(14.67)
Percentage of self-business households (%, 1995)	7.45	4.1*	3.02**	4.75
	(9.81)	(4.23)	(4.17)	(6.99)

Table 4 continued on next page.

Table 4 (Continued)

	Collective management	Water user association	Contracting	Other institutions
Characteristics of village leaders				
Age of the party secretary (Year)	47.86	49.14	46.54	48.14
	(7.38)	(6.15)	(6.16)	(3.08)
Level of education of party secretary (Years of schooling)	9.21	9.36	8.33*	9.43
	(2.54)	(2.28)	(2.58)	(3.64)
Job dummy (1= the main job of the party secretary is NOT agriculture in 2004)	0.13	0.14	0**	0.14
	(0.33)	(0.35)	0.00	(0.38)
Years of water management experience of the party secretary	5.19	6.91	4.85	5.29
	(6.90)	(6.85)	(5.46)	(5.96)
Village demography				
Level of education of villagers (%, share of 1995 labor force that had education above high school)	1	2.7***	6.91***	10***
	(2.71)	(4.11)	(7.25)	(9.24)
Number of household in the village in 2004	444	461	429	389
	(376)	(178)	(167)	(201)
Location dummies				
Irrigation district location dummy (1=village located downstream of an irrigation district in 2004 and 0=otherwise)	0.42	0.5	0.33	0.71*
	(0.50)	(0.51)	(0.48)	(0.49)

a Other institutions includes the four types of mixed institutions: 1) water user association combined with collective management; 2) water user association combined with contracting; 3) contracting combined with collective management; 4) water user association, contracting and collective management.

b Villages that used surface water for irrigation in both 1995 and 2004 are included in the analysis. Hebei Province and Henan Province are not included since there are no variations in water management institutions among villages in these two provinces.

c Standard deviations of variables are reported in parentheses.

d Asterisks indicate a variable has different means between villages under collective management villages and villages under other institutions. * denotes the difference is significant at 10%; ** significant at 5%; *** significant at 1%.

Source of Data: 2004 NCWRS and CWIM 2001-2004 Panel

Table 5. Logit regression explaining determinants of water management institutional reform.

Dependent variable: Non-collective management dummy (=0 if collective management and =1 if otherwise) a	Model without fixed effects	Model with province fixed effects
Characteristics of water resources in the village		
Water availability (Number of years that there was not enough water in canals between 1993 and 1995)	-0.507**	-0.555**
	(1.98)	(2.08)
Village water scarcity indicator variable (1= water is scarce in the village in 1995, 0=otherwise)	0.104	0.145
	(0.10)	(0.11)
Conjunctive use (Percentage of land that is conjunctively Irrigated by surface water and groundwater in 1995, %)	0.030***	0.028***
	(3.35)	(2.91)
Characteristics of canals in the village		
Canal lining (Percentage of the total length of tertiary canals that is lined in 2004, %)	-0.007	-0.006
	(0.71)	(0.67)
Canal length (Total length of tertiary canals in the village in 2004, Km)	0.052**	0.050**
	(2.52)	(2.19)
Policy Dummy (1=government promoted water user association or contracting and 0=otherwise)	1.959***	1.794***
	(3.53)	(2.69)
Cropping pattern Share of sown area in rice in 1995 (%)	-0.020**	0.009
	(2.08)	(0.65)
Socioeconomic characteristics of villages		
Income per capita in 1995 (Yuan, in log form)	0.672	0.617
	(1.30)	(0.95)
Percentage of migrants (%, share of village labor force	0.007	0.010
that out migrated in 1995)	(0.39)	(0.47)
Percentage of self-business households (%, 1995)	-0.048	-0.034
	(1.38)	(0.81)

Table 5 continued on next page.

Table 5 (Continued)

Dependent variable: Non-collective management dummy (=0 if collective management and =1 if otherwise)	Model without fixed effects	Model with province fixed effects
Characteristics of village leaders		
Age of the party secretary (Year)	0.063	0.050
	(1.64)	(1.26)
Level of education of party secretary (Years of schooling)	0.103	0.016
	(1.01)	(0.15)
Job dummy (1= the main job of the party secretary is NOT agriculture in 2004)	0.243	-0.309
	(0.28)	(0.33)
Years of water management experience of the party secretary	0.011	0.033
	(0.29)	(0.74)
Village demography		
Level of education of villagers (%, share of 1995 labor force that had education above high school)	0.158**	0.153**
	(2.53)	(1.96)
Number of household in the village in 2004	-0.001	0.000
	(0.81)	(0.03)
Location dummies		
Irrigation district location dummy (1=village located downstream of an irrigation district in 2004 and 0=otherwise)	-0.274	-0.343
	(0.53)	(0.61)
Constant	-10.416**	-9.760**
	(2.49)	(2.08)
Observations	160	160

a Non-collective management includes WUA and contracting.
b Villages that used surface water for irrigation in both 1995 and 2004 are included in the regression. Hebei Province and Henan Province are not included since there are no variations in water management institutions among villages in these two provinces.
c Absolute value of z statistics in parentheses, significant at 10%; ** significant at 5%; *** significant at 1%
Source of Data: 2004 NCWRS and CWIM 2001-2004 Panel

Table 6. Logit regression explaining determinants of water management institutions

Dependent variable: Water user association dummy (=1 if water user association exists in the village)	Model without fixed effects	Model with province fixed effects
Characteristics of water resources in the village		
Water availability (Number of years that there was not enough water in canals between 1993 and 1995)	-0.625*	-0.842*
	(1.66)	(1.73)
Village water scarcity indicator variable (1= water is scarce in the village in 1995, 0=otherwise)	-1.317	-0.483
	(1.42)	(0.41)
Conjunctive use (Percentage of land that is conjunctively irrigated by surface water and groundwater in 1995, %)	0.026**	0.031*
	(2.21)	(1.83)
Characteristics of canals in the village		
Canal lining (Percentage of the total length of tertiary canals that is lined in 2004, %)	0.002	0.000
	(0.21)	(0.02)
Canal length (Total length of tertiary canals in the village in 2004, Km)	0.002	0.013
	(0.22)	(0.84)
Policy Dummy (1=government promoted water user association or contracting and 0=otherwise)	3.563***	3.090***
	(3.91)	(2.92)
Cropping pattern Share of sown area in rice in 1995 (%)	-0.018	0.052*
	(1.48)	(1.91)
Socioeconomic characteristics of villages		
Income per capita in 1995 (Yuan, in log form)	1.697**	3.738***
	(2.39)	(2.59)
Percentage of migrants (%, share of village labor force that out migrated in 1995)	0.015	0.011
	(0.71)	(0.47)
Percentage of self-business households (%, 1995)	-0.039	-0.056
	(0.86)	(0.76)

Table 6 continued on next page.

Table 6 (Continued)

Dependent variable: Water user association dummy (=1 if water user association exists in the village) a	Model without fixed effects	Model with province fixed effects
Characteristics of village leaders		
Age of the party secretary (Year)	0.173***	0.149*
	(3.04)	(1.83)
Level of education of party secretary (Years of schooling)	0.236*	-0.068
	(1.67)	(0.35)
Job dummy (1= the main job of the party secretary is NOT agriculture in 2004)	2.317**	1.446
	(1.98)	(1.11)
Years of water management experience of the party secretary	-0.029	0.003
	(0.61)	(0.04)
Village demography		
Level of education of villagers (%, share of 1995 labor force that had education above high school)	-0.010	0.058
	(0.19)	(0.64)
Number of household in the village in 2004	-0.002**	0.000
	(2.15)	(0.18)
Location dummies		
Irrigation district location dummy (1=village located downstream of an irrigation district in 2004 and 0=otherwise)	1.020	-0.013
	(1.62)	(0.01)
Constant	-25.494***	-36.658***
	(3.91)	(3.19)
Observations a	137	137

a WUA includes villages under WUA or under WUA combined with other institutions.
b Villages that used surface water for irrigation in both 1995 and 2004 are included in the regression. Hebei Province, Henan Province and Shanxi Province are not included since there are no variations in water management institutions among villages in these three provinces.
c Absolute value of z statistics in parentheses, significant at 10%; ** significant at 5%; *** significant at 1%
Source of Data: 2004 NCWRS and CWIM 2001-2004 Panel

Appendix Table 1. Number of sample villages and nature of their irrigation systems in northern China study area and sample provinces, 2004.

	(1) Total number of villages [a]	Number of villages that				(6) Sample villages In our study [d]
		(2) Used surface water in 2004 [b]	(3) Only used groundwater in 2004	(4) Did not irrigate in 2004	(5) Used surface water but did not have any canals [c]	
North China	481	234	185	62	12	222
CWIM	80	61	19	0	0	61
NCWRS	401	173	166	62	12	161
Hebei	80	25	53	2	1	24
Henan	80	22	37	21	1	21
Shaanxi	72	46	10	16	1	45
Shanxi	73	25	31	17	0	25
Inner Mongolia	72	36	33	3	2	34
Liaoning	72	48	21	3	7	41
Ningxia	32	32	0	0	0	32

[a] * (1) = (2) +(3)+(4)

[b] These villages either used surface water or used surface water and groundwater conjunctively in 2004

[c] These villages often used pump to lift water directly from a river to farmers' fields or obtained water from other storage facilities such as ponds.

[d] Column (6)=column (2)- column (5)

**Data Source: 2004 NCWRS and CWIM.*

Appendix Table 2. Number of sample villages nature of their irrigation systems in northern China study area and sample provinces, 1995.

	(1) Total number of villages [a]	Number of villages that				(6) Sample villages in our study [d]
		(2) Used surface water in 1995 [b]	(3) Only used groundwater in 1995	(4) Did not irrigate in 1995	(5) Used surface water but did not have any canals [c]	
North China	80	67	13	0	1	66
CWIM	401	183	146	72	14	169
NCWRS	481	250	159	72	15	235
Hebei	80	24	54	2	1	23
Henan	80	34	30	16	2	32
Shaanxi	72	41	15	16	4	37
Shanxi	73	28	25	20	0	28
Inner Mongolia	72	39	27	6	2	37
Liaoning	72	52	8	12	6	46
Ningxia	32	32	0	0	0	32

[a] * (1) = (2) +(3)+(4)

[b] These villages either used surface water or used surface water and groundwater conjunctively in 1995

[c] These villages often used pump to lift water directly from a river to farmers' fields or obtained water from other storage facilities such as ponds.

[d] Column (6)=column (2)- column (5)

**Data Source: 1995 NCWRS and CWIM.*

Appendix Table 3. Water management institutional forms in northern China sample villages in 2004.

	Number of sample villages	Number of villages that have						
		Collective management	Water user association	Contracting	Water user association and collective management	Water user association and contracting	Contracting and collective management	Water user association, contracting and collective management
North China	222	161 (72.5) [a]	23 (10.4)	29 (13.1)	4 (1.8)	2 (0.9)	2 (1.1)	1 (0.5)
Inner Mongolia	34	15 (44.1)	13 (38.2)	4 (11.8)	2 (5.9)			
Ningxia	32	10 (31.3)	4 (12.5)	14 (43.8)	1 (3.1)	2 (6.3)		1 (3.1)
Liaoning	41	37 (90.2)	2 (4.9)	2 (4.9)				
Shaanxi	45	39 (86.7)	4 (8.9)		1 (2.2)		1 (2.2)	
Shanxi	25	20 (80.0)		5 (20.0)				
Hebei	24	20 (83.3)		4 (16.7)				
Henan	21	20 (95.2)					1 (4.8)	

[a] Figures in parenthesis are the percentages of sample villages that have the water management institution listed in the column head.
Source of data: 2004 NCWRS and 2004 CWIM

Appendix Table 4. Water management institutions in northern China sample villages in 1995.

	Number of sample villages	Number of villages that have						
		Collective management	Water user association	Contracting	Water user association and collective management	Water user association and contracting	Contracting and collective management	Water user association, contracting and collective management
North China	235	211 (89.8) [a]	8 (3.4)	11 (4.7)	1 (0.4)	1 (0.4)	2 (0.9)	1 (0.4)
Inner Mongolia	37	33 (89.2)	3 (8.1)	1 (2.7)				
Ningxia	32	25 (78.1)	1 (3.1)	3 (9.4)		1 (3.1)	1 (3.1)	1 (3.1)
Liaoning	46	44 (95.7)	1 (2.2)	1 (2.2)				
Shaanxi	37	31 (83.8)	3 (8.1)	1 (2.7)	1 (2.7)		1 (2.7)	
Shanxi	28	27 (96.4)		1 (3.6)				
Hebei	23	19 (82.6)		4 (17.4)				
Henan	32	32 (100)						

[a] Figures in parenthesis are the percentages of sample villages that have the water management institution listed in the column head.
Source of data: 2004 NCWRS and 2001 CWIM

Appendix Table 5. Multinomial regression explaining the choice of water management institutions in sample villages.

Base category: Collective management	Model without fixed effects		Model with province fixed effects	
	Contracting a	WUA b	Contracting	WUA
Characteristics of water resources in the village				
Water availability (Number of years that there was not enough water in canals between 1993 and 1995)	-0.417	-0.783**	-0.420	-0.981*
	(1.36)	(2.06)	(1.36)	(1.95)
Village water scarcity indicator variable (1= water is scarce in the village in 1995, 0=otherwise)	0.253	0.070	0.603	1.033
	(0.18)	(0.04)	(0.37)	(0.34)
Conjunctive use (Percentage of land that is conjunctively irrigated by surface water and groundwater in 1995, %)	0.033***	0.034***	0.029**	0.038**
	(2.69)	(2.74)	(2.41)	(2.10)
Characteristics of canals in the village				
Canal lining (Percentage of the total length of tertiary canals that is lined in 2004, %)	-0.021	0.001	-0.019	-0.005
	(1.35)	(0.05)	(1.18)	(0.32)
Canal length (Total length of tertiary canals in the village in 2004, Km)	0.065**	0.059**	0.061**	0.064**
	(2.50)	(2.38)	(2.14)	(2.07)
Policy Dummy (1=government promoted water user association or contracting and 0=otherwise)	0.978	3.345***	0.668	3.152***
	(1.25)	(3.99)	(0.68)	(3.06)
Cropping pattern Share of sown area in rice in 1995 (%)	-0.043**	-0.016	-0.032	0.046*
	(2.35)	(1.34)	(1.45)	(1.71)
Socioeconomic characteristics of villages				
Income per capita in 1995 (Yuan, in log form)	-0.785	1.588**	-0.981	3.509**
	(0.95)	(2.11)	(1.06)	(2.32)
Percentage of migrants (%, share of village labor force that out migrated in 1995)	-0.016	0.013	-0.019	0.009
	(0.64)	(0.57)	(0.70)	(0.36)
Percentage of self-business households (%, 1995)	-0.034	-0.057	-0.015	-0.054
	(0.56)	(1.15)	(0.24)	(0.73)

Appendix Table 6 continued on next page.

Appendix Table 5 (Continued)

Base category: Collective management	Model without fixed effects		Model with province fixed effects	
	Contracting	WUA	Contracting	WUA
Characteristics of village leaders				
Age of the party secretary (Year)	0.012	0.148***	0.009	0.141*
	(0.27)	(2.63)	(0.19)	(1.74)
Level of education of party secretary (Years of schooling)	-0.072	0.234	-0.053	-0.107
	(0.51)	(1.59)	(0.36)	(0.55)
Job dummy (1= the main job of the party secretary is NOT agriculture in 2004)	-34.158	1.925*	-42.966	1.305
	(0.00)	(1.73)	(0.00)	(0.97)
Years of water management experience of the party secretary	0.015	0.009	0.036	0.032
	(0.30)	(0.20)	(0.68)	(0.42)
Village demography				
Level of education of villagers (%, share of 1995 labor force that had education above high school)	0.238***	0.113	0.154	0.115
	(3.05)	(1.56)	(1.64)	(1.10)
Number of household in the village in 2004	0.002	-0.002*	0.002	0.000
	(1.20)	(1.87)	(1.05)	(0.18)
Location dummies				
Irrigation district location dummy (1=village located downstream of an irrigation district in 2004 and 0=otherwise)	-1.016	0.371	-0.874	-0.441
	(1.41)	(0.56)	(1.16)	(0.47)
Constant	2.873	-24.113***	3.116	-34.582***
	(0.48)	(3.56)	(0.48)	(2.97)
Observations a	160	160	160	160

a Contracting includes villages under contracting and villages under contracting combined with collective management.
b WUA includes villages under WUA or under WUA combined with other institutions.
c Villages that used surface water for irrigation in both 1995 and 2004 are included in the regression. Hebei Province and Henan Province are not included since there are no variations in water management institutions among villages in these two provinces.
d Absolute value of z statistics in parentheses, *significant at 10%; ** significant at 5%; *** significant at 1%.
Source of Data: 2004 NCWRS and CWIM 2001-2004 Panel