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Water management institutional reform: A representative look at northern China

Qiuqiong Huang [a,*], Scott Rozelle [b], Jinxia Wang [c], Jikun Huang [c]

[a] Department of Applied Economics, University of Minnesota, United States
[b] Shorenstein Asia Pacific Research Center, Freeman Spogli Institute for International Studies, Stanford University, United States
[c] Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, China

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ABSTRACT

Our goal is to provide information regarding water management reform in China by increasing understanding of newly emerging water institutions and identifying factors that lead to the creation of reform-oriented irrigation institutions (Water User Associations and/or contracting) in one place but not in another. Using two sets of survey data, one of which is representative of northern China, we find that water management reform has spread steadily. Between 20% and 30% of villages in northern China have shifted away from traditional forms of management. In their places, some villages are hiring individual contractors; others are adopting Water User Associations. While China's new forms of water governance are not very participatory (from the farmer's point of view), water managers—especially contractors—are increasingly being given more incentives to save water and to manage their village's water more effectively. Water scarcity, other village characteristics, and policies implemented by local and regional government water officials are the main drivers of water management reform.

1. Introduction

Increasing demand for China's limited water resources from rapidly growing industry, urban populations and agriculture implies potentially dire consequences for the sustainability of water resources, especially in northern China (Zhang, 2001). In addition to the existing pressure on the irrigation water supply in the agricultural sector, China's government has stated that agricultural users will not be given priority for any additional future sources of water (World Bank, 1993). Problems in the water sector will no doubt affect China's future trade position in key crops and incomes in the farming sector (Huang et al., 1999).

Despite the seriousness of the water problem, China's government has responded slowly in addressing growing water shortages (Wang et al., 2007). There are many laws and formal regulations specifying how villages should use and manage water. Unfortunately, only a few of these measures have been effectively implemented. Although the leaders have encouraged users to adopt water saving technologies since the early 1990s, the adoption rates are very low in China, even in water scarce areas (Blanke et al., 2007). For many technologies, such as plastic sheeting, sprinkler systems, drought resistant varieties, and drip irrigation, the average adoption rates in northern China villages are less than 20%.

The record on water pricing in agriculture is equally poor (Huang et al., 2008a). Although water officials increasingly emphasize the need to promote water prices to encourage water savings, there has been little progress. In many cases, physical factors—especially the small scale and fragmented

* *Corresponding author at*: 249e Classroom Office Building, 1994 Buford Avenue, St. Paul, MN 55108, United States. Tel.: +1 612 624 1692; fax: +1 612 625 6245.
E-mail address: qhuang@umn.edu (Q. Huang).
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nature of China's farms—preclude accurate measuring of water at the farm level and so volumetric pricing is difficult. Instead, farmers pay for water on a per unit of land basis. In addition, political economy factors dampen the enthusiasm of policy makers to raise the cost of water, which will negatively affect farmers' incomes. China's leaders are intent on continuing to alleviate poverty in rural China. Tax reform policies that seek to eliminate taxation on rural households have been implemented during the past decade. With such a policy environment, there will be strong resistance against any policy that results in lower rural incomes. As a result, the use of water prices to motivate improvements in farm-level water management is quite rare in China (Wang et al., 2006).

In contrast to the government's slow response, water users have been more active. Several institutions – created by farmers and village leaders – have emerged in the wake of rising scarcity (Chen, 2002; Fang, 2000). Internationally, since the 1980s many developing countries have transferred irrigation management responsibilities from the government to farmer organizations or other private entities (Vermillion, 1997). Water User Associations (WUAs), have been shown to be effective in raising the efficiency of irrigation, increasing incomes, and helping poor farmers (World Bank, 1993). However, beyond a relatively few internationally funded sites, little is known about WUAs and other forms of water management institutions—especially inside China.

The lack of information in China on WUAs and other institutions is surprising, given the emphasis on the role of water management reforms. In particular, little is known about exactly where WUAs have emerged and in what numbers. There is little information about the villages in which new institutions have emerged. The few existing studies have demonstrated mixed impacts on farmer welfare. For example, Zhang (2001) and Nian (2001) conclude that WUAs are successful. In contrast, Wang et al. (2005b) find that WUAs have not been universally successful in either saving water or improving farmer incomes. Instead, contracting canals to individual managers, an alternative institution that is prevalent in many different contexts of China's reforms (Park and Rozelle, 1998) was more successful.

In addition to the limited number of existing studies, most research focuses on villages that span narrow geographic areas. Zhang (2001) studies only World Bank project sites. Wang et al. (2005b) examine only four irrigation districts in two provinces. There is little, if any, nationwide empirical research analyzing whether or not institutional reforms help alleviate China's water crisis, or how the reforms have affected the welfare of farmers.

Our goal in this paper is to improve knowledge and overcome the general absence of information regarding water management reform in China by increasing understanding of newly emerging water institutions and identifying factors that lead to the creation of reform-oriented irrigation institutions (WUAs and/or contracting) in one place but not in another. To meet these goals, we pursue three objectives. First, we document the evolution of existing and new water management institutional forms over time and across provinces throughout northern China. Second, we describe the characteristics of WUA governance and compare them to traditional collectively managed irrigation systems and contracting. Finally, we analyze the determinants of the emergence of these institutions throughout northern China to understand the role of water scarcity, the size of a village's irrigation system, government policy, and other village characteristics in water management reform.

2. Data

Broad-scale data describing China's surface water uses and the institutions that govern them are extremely limited. We use data collected by the authors in two recent field surveys. The first survey, the *China Water Institutions and Management* survey (CWIM), was conducted in September 2004. Enumerators interviewed village leaders, surface water irrigation managers and farmers in 80 villages in Hebei, Ningxia and Henan provinces. The 2004 CWIM survey is a continuation of the 2001 CWIM survey, thus providing us a set of panel data.

The second survey, the *North China Water Resource Survey* (NCWRS), was conducted in January 2005. To generate a sample representative of northern China, the study team designed a stratified random sampling strategy. To do so, we first randomly chose six provinces: Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi. Next, the research team divided the counties in each province into four water scarcity categories: very scarce, somewhat scarce, normal and mountain/desert. Two townships within each county and four villages within each township were then randomly selected. In total, the data collection team visited 60 counties, 126 townships and 401 villages. In the NCWRS survey we only interviewed village leaders due to limitations in time and budget. During the interviews, the survey teams used a more comprehensive version of the village leader questionnaire used in the CWIM survey. Data were collected on most variables for two years, 2004 and 1995. Because of its representativeness, the NCWRS data form the basis of our analyses. The CWIM survey data are used primarily to supplement the findings that are from village leaders.

The scopes of the surveys were quite broad. Each of the survey instruments included sections that focused on the nature of water resources in the villages, government policies, adoption of water saving technology and the condition of village irrigation infrastructure. The key section of the survey for this paper came from the surface water management block. In each village the enumerator asked the respondent a series of questions about how the surface water system was managed in his village. For example, the survey included questions about each major task that was conducted to operate and maintain village canals. We also asked who was responsible for each task. Based on the answers of each respondent, we determined the type of water management form in each village. The survey form also contained questions about the incentives faced by the manager in each village and the extent of participation by farmers. In the CWIM survey, we also sought to understand how the water management reforms were being implemented from the point of view of the farmers.

3. Trends in northern China's water management reform, 1995–2004

Based on our field surveys, surface water is managed in three general ways. If the village leaders (that is, the village council) directly take 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 had allocated water in most of China's villages during the People's Republic period. In this paper we refer to the collective management system as the traditional system. In contrast, a *WUA* is in principle a farmer-based, participatory organization that manages the village's irrigation water. In WUAs, a board, which is supposedly elected by villagers, manages the village's water and facilitates farmer participation. *Contracting* is a system in which the village leaders contract the village's canal out to an individual, who manages the canal in return for a payment that may or may not be related to the size of water savings the individual can achieve. We consider WUAs and contracting to be reform-oriented management systems.

3.1. Changes over time

According to our data, WUAs and contracting have gradually emerged in northern China between 1995 and 2004. However, tracking these changes is complicated by the changing nature of China's water resources (Table 1). In 1995, of the 481 sample villages, 235 had surface water irrigation (column 1, row 9). During the survey, the enumerators learned that of the 235 villages, 30 of them had stopped using surface water by 2004 (row 8). During the same period, 17 villages used surface water in 2004 but not in 1995 (row 10). In total, 205 villages (235 − 30) used surface water in both 1995 and 2004.

When examining the villages that used surface water in both 1995 and 2004, our data reveal a clear tendency in the ways that villages are reforming their water management structure (Table 1, row 1). Of the 181 villages that were being managed under collective management in 1995 only 143 were still managed in this way in 2004 (columns 1 and 2). This means 38 villages (21%) implemented some form of water management reform.

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

While the trends in northern China's village are 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. 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 (Table 1, row 2, columns 1, 2 and 5). Two of the 11 villages that chose contracting systems in 1995 decided to either fully or partially go back to collective

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	(1) Number of sample villages	Forms of surface water management in 2004						
		(2) Collective management	(3) Water user association (WUA)	(4) Contracting	(5) WUA and collective management	(6) WUA and contracting	(7) Contracting and collective management	(8) WUA, contracting and collective management
1 Collective management	181	143	14	18	2	2	1	1
2 WUA	8	2	5		1			
3 Contracting	11	1		9			1	
4 WUAs and collective management	1		1					
5 WUAs and contracting	1		1					
6 Contracting and collective management	2	1		1				
7 WUAs, contracting and collective management	1		1					
8 Villages that shut down SW irrigation between 1995 and 2004	30							
9 Total villages with SW irrigation in 1995	235	–	–	–	–	–	–	–
10 Villages with new SW irrigation created between 1995 and 2004	17	14	1	1	1			

Source of Data: 2004 NCWRS and 2001–2004 CWIM Panel.

management by 2004 (row 3, columns 1, 2 and 7). These shifts into and out of WUAs and contracting may indicate that water management reform is not universally successful. This is of concern to national leaders worried about whether or not surface water management reform is suitable to China's villages.

The emergence of water management reform is not closely tied with the creation of new irrigation systems (Table 1, row 10). In the 17 villages that used surface water in 2004 but not in 1995, 14 (82%) chose to be managed under the collective management system. Only three chose to implement WUA or contracting. This percentage of reformed management villages (among newly irrigated villages—18%) is lower than the overall average.

So how should one interpret the trend of water management reforms between 1995 and 2004 in northern China? Our data show that the changes were significant (Fig. 1). The share of collective management declined from 90% in 1995 to 73% in 2004. WUAs and contracting have developed at about the same pace. By 2004, 10% of villages managed their surface water through WUAs and 13% through contracting. The mixed systems also rose from 2% to 4% between 1995 and 2004. While collective management still is the dominant form of management, 27% of villages in northern China had been affected by water management reform by 2004.

3.2. *Differences across space*

Although the overall trend during the past decade was the shift from collective management to WUAs or contracting, water management reform varies significantly across the seven sample provinces, showing that the nature of reforms is not universal (Table 2). For example, the use of collective management between 1995 and 2004 has fallen in five sample provinces: Inner Mongolia, Ningxia, Liaoning, Shanxi and Henan (rows 2–4, 6 and 8, column 1). In Shaanxi and Hebei (rows 5 and 7, column 1), however, the use of collective management actually increased. Moreover, even among the five reforming provinces, there were striking differences. In Inner Mongolia the share of collective management fell sharply from 89% in 1995 to 44% in 2004. In Ningxia the share of collective management also fell sharply from 78% in 1995 to 31% in 2004. Villages in the other three provinces (Liaoning, Shanxi and Henan) reformed significantly less. The share of villages under collective management fell by only 5–10 percentage points.

Beyond the differences across the villages regarding their decision to reform or not, the direction of reform also varied among provinces (Table 2). Most poignantly, when examining the nature of reforms in Inner Mongolia, one of the two actively reforming provinces, in almost all the sample villages that had reformed by 2004, villagers decided to manage their surface water systems through WUAs instead of contracting (15 of 19, row 2, columns 2–4). In contrast, villages in the other actively reforming province, Ningxia, chose mostly contracting. There also were differences in other provinces. Villagers in all of the reforming villages in Shanxi and Hebei chose contracting; while five of the six reforming villages in Shaanxi chose WUAs.

Although some of the differences in water management may be due to differences in local villages, the dramatic differences among provinces suggest that government policy may also play an important role. For example, in 2000 Ningxia provincial water officials issued several documents that encouraged local governments to proceed with water management reform (Wang, 2002). Regional water officials exerted considerable effort to promote water management reform in several experimental areas. In contrast, in Hebei (a non-reforming province) when we approached provincial officials about WUAs, no one knew anything about them. The sharp shift away from collective management in provinces whose leaders were supportive of reforms shows that these policy measures were effective in pushing reform forward. For example, contracting has risen rapidly after provincial officials relaxed the previous restrictions against contracting out the village's irrigation system.

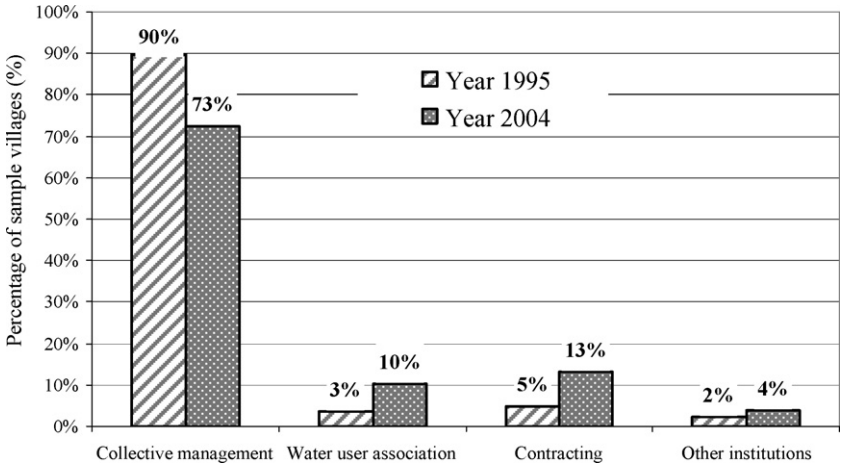

Fig. 1 – Changes in water management institutions from 1995 to 2004.
***Note*: Other institutions includes the four types of mixed institutions: (1) water user association combined with collective management; (2) water user association combined with contracting; (3) contracting combined with collective management; (4) water user association, contracting and collective management.**

4. Differences in governance among water management institutions

The shift in China's water management institutions demonstrates that rural villages are at least in part following policy directives that are developed and issued from upper level governments. The differences among regions, however, show that the nature of reform is not universal. The regional differences are likely characteristic of reform in China, where local governments often are given considerable room in choosing the exact form and timing of changes (Jin et al., 2005). In this section we examine the differences among the governance approaches in villages that have chosen different forms of water management: collective management, WUAs and contracting.

4.1. *Operation and maintenance responsibilities*

According to our data, when villages report their water systems are being run under a certain institutional form, there are major shifts of responsibilities (Table 3). When a village claims its surface water system is being managed under the collective management system, nearly all water management activities are carried out by the village leadership (rows 1–5). In all villages, canal maintenance, coordination of water delivery and water fee collection are fully the responsibility of the village council. In a small portion of villages (22%) farmers themselves must operate the sluice gates according to a schedule set by village leaders. Some villages (33%) also depended on township or irrigation district (ID) officials if there was a dispute that required resolution.

When a WUA is formed, most responsibilities are transferred to the WUA board (Table 3, rows 6–10), which is fully responsible for some of the main tasks including the operation of sluice gates, water fee collection and conflict resolution. In half of the villages with WUAs, the WUA was responsible for canal maintenance, but in the other half, the village leadership maintained responsibility. According to our observations this is done in some WUAs because in some areas of rural China a village is divided into several small groups or *xiaozu* (and the plots of households in each small group are located together); while canal maintenance in some villages is carried out by small group members, the WUA is a village-wide organization and so the village leadership is still needed to coordinate among the small groups. WUAs also share responsibilities with village leaders and farmers for coordination of water delivery.

The organization of water management activities is more complicated when contracting is used (Table 4, rows 11–15). In contracting villages, the village council helps the contractor conduct all of the different activities, in part because contractors may lack the ability to conduct some activities (e.g., canal maintenance). In addition, some contractors are unable to act as a disinterested party when conducting other activities, such as dispute resolution.

4.2. *Incentives*

Although there are many similarities between international experiences and those of China, even in its early phase, policy

Table 2 – Number of villages that are under different water management forms in northern China in 1995 and 2004

	(1) Collective management		(2) WUA		(3) Contracting		(4) WUA and collective management		(5) WUA and contracting		(6) Contracting and collective management		(7) WUA, contracting and collective management	
	2004	1995	2004	1995	2004	1995	2004	1995	2004	1995	2004	1995	2004	1995
1 North China	161 (72.5)	211 (89.8)	23 (10.4)	8 (3.4)	29 (13.1)	11 (4.7)	4 (1.8)	1 (0.4)	2 (0.9)	1 (0.4)	2 (1.1)	2 (0.9)	1 (0.5)	1 (0.4)
2 Inner Mongolia	15 (44.1)	33 (89.2)	13 (38.2)	3 (8.1)	4 (11.8)	1 (2.7)	2 (5.9)							
3 Ningxia	10 (31.3)	25 (78.1)	4 (12.5)	1 (3.1)	14 (43.8)	3 (9.4)	1 (3.1)		2 (6.3)	1 (3.1)		1 (3.1)	1 (3.1)	1 (3.1)
4 Liaoning	37 (90.2)	44 (95.7)	2 (4.9)	1 (2.2)	2 (4.9)	1 (2.2)								
5 Shaanxi	39 (86.7)	31 (83.8)	4 (8.9)	3 (8.1)		1 (2.7)	1 (2.2)	1 (2.7)			1 (2.2)	1 (2.7)		
6 Shanxi	20 (80.0)	27 (96.4)			5 (20.0)	1 (3.6)								
7 Hebei	20 (83.3)	19 (82.6)			4 (16.7)	4 (17.4)								
8 Henan	20 (95.2)	32 (100)									1 (4.8)			

Figures in parentheses are the percentages of sample villages that have the water management institution identified by the column head. This table counts all sample villages that used surface water in 2004 and all sample villages that used surface water in 1995. Because of this, the number of villages is different from those in Table 1. The total number of villages in 1995 and in 2004 may not add up to be the same either because some villages stopped surface water irrigation while others created new surface water irrigation between 1995 and 2004. *Source of data:* 2004 NCWRS and 2004 CWIM.

Table 3 – Division of responsibilities (water management activities) under different water management institutional forms in northern China sample villages, 2004

Water management institution	Water management activity	Percentage of sample villages in which a water management activity is carried out by (%)				
		Village council	Water user association	Contractor	Contractor and village council	Others[a]
Collective management (n = 161)	1 Canal maintenance	100				
	2 Operation of sluice gates	78				22
	3 Coordination of water delivery	100				
	4 Water fee collection	100				
	5 Conflict resolution	67				33
Water user association (n = 23)	6 Canal maintenance	50	50			
	7 Operation of sluice gates		100			
	8 Coordination of water delivery	25	50			25
	9 Water fee collection		100			
	10 Conflict resolution		100			
Contracting (n = 29)	11 Canal maintenance	35		25	35	5
	12 Operation of sluice gates			90	5	5
	13 Coordination of water delivery	10		75	5	10
	14 Water fee collection	10		80	10	
	15 Conflict resolution			50	35	15

[a] Others include farmers, irrigation district and township government. *Source of data*: 2004 NCWRS and CWIM.

documents emphasize certain things that make China's water management reform unique. Above all, water officials have promoted the idea of using incentives to make water management reform more effective. The use of incentives 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 was based on new profit incentives for farmers (Lin, 1992). Fiscal reforms gave local leaders strong incentives to begin township and village enterprises (Walder, 1995), while grain reforms gave grain bureau personnel incentives to commercialize commodity trading (Rozelle et al., 2000).

With the past success of using incentives in various reforms, water officials are hoping similar policy efforts would improve water management in China. In many of the new reform efforts, water managers are supposed to be provided with monetary rewards if they achieve water saving objectives. In our analysis, village leaders are the managers of collectively managed irrigation systems. The chair of the WUA board is the manager in villages with WUAs, while the contractor is the manager in contracting villages. If a canal manager is provided with earning incentives, he or she can claim all or part of the profits from the operation of a canal. Usually a canal manager is either paid a portion of the water fees collected or a portion of the residual profit from canal operation.

Table 4 – 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 (%)	
	2004	1995
Collective management	0	0
Water user association	32	14
Contracting	73	27

Source of data: 2004 NCWRS.

The differences in incentives faced by managers vary across institutional forms and over time (Table 4). In none of the collectively managed villages were village leaders paid a bonus or given any portion of the residual revenues in either 1995 or 2004. In contrast, managers in WUA villages faced better incentives. In 14% the villages with WUAs, WUA managers were provided with incentives. The share rose to 32% in 2004. Despite the rising trend, however, WUA managers in more than two thirds of villages still faced no incentives of any kind.

In contrast, the incentives faced by contractors rose rapidly and reached a high proportion of villages by 2004. Although only 27% of contracting villages offered contractor-cum-managers financial incentives in 1995, the proportion reached 73% in 2004. Clearly, the provision of incentives distinguishes contracting significantly from collective management or WUAs.

4.3. *Practice and principle: participation*

So far, we have only reported the results from the NCWRS survey. Although this is a comprehensive survey, it relies only on the opinion of village leaders. In such a survey it is impossible to check the validity of some answers due to the lack of an alternative source of information. In the CWIM survey, we interviewed multiple stakeholders including village leaders, canal managers and farmers. Separate sets

of survey instruments were used and the answer of each respondent was held in confidence from all others. Hence we have more accurate information to assess the practices of reformed irrigation management systems, and whether they vary from principle. In particular, we can assess the level of participation in water management by different stakeholders. In our survey we inquired about three major dimensions of participation: how much farmers participated in the process of the establishment of the reform process; whether or not farmers were involved in the selection of the managers; and whether or not farmers were invited to attend regular meetings. These three aspects cover nearly all the major decision making in water management institutions.

According to our data, participation is not part of either collective management or contracting. Traditionally, many government services in China are conducted from the top down, with little consultation or participation of farmers (Zhang et al., 2003). Although collectively managed services, such as those provided by collectively run water organizations, in principle are supposed to be determined by the entire collective, in reality, village leaders have managed their villages largely based on the authority they have derived from higher level officials. In our sample villages we find that farmers participated little (and mostly not at all) in collectively run water management organizations. Similarly, contracting only involved transferring control and income rights to an individual. Village leaders usually decided whether to contract out canals or not. Farmers often played no role in the transition. Only in a few villages did farmers participate in electing the contractor.

Even when the reforms that led to the creation of WUAs explicitly attempted to encourage farmer participation, practice often varied from principle. In the CWIM survey areas, farmers had little voice in deciding the establishment of WUAs or appointing the WUA board members. For example, our data show that, on average, only about 12.5% of WUAs involved farmers in the decision on their establishment. In fact, most farmers (70%) did not know they were members of a WUA. If the motivation of promoting WUAs is to increase participation by farmers, the canal system in these villages is only being nominally managed by WUAs.

Farmers also were seldom encouraged to participate in other aspects of water management. Based on our sample, *none* of the WUA board members actually were elected by farmers. Only 25% of WUAs allowed farmers to participate in selecting managers. As a result, in most cases (70% of the WUAs), the WUA board was comprised of the village leadership. In a few cases (30% of the WUAs), village leaders appointed a chair or manager to conduct the daily duties of the WUAs. In many of these WUAs, however, the managers had close ties to the village leadership. For example, the manager frequently was a former village leader or a relative of the current leader. Moreover, although 80% of WUAs conducted regular meetings, only in 25% of the WUAs were farmers invited to participate.

Compared with collective management and contracting, however, our data show that management under WUAs was more transparent. Nearly 40% of WUAs shared three types of information about irrigation management with farmers, including the total amount of water fees collected, the volume of water actually delivered by the irrigation district to the village, and the actual area irrigated. About 50% of the WUAs shared two of the three types of information with farmers.

5. Why are WUAs and contracting used in some areas but not others?

The data described above suggest that although many villages in northern China are reforming their water management institutions, reform is happening in some places but not in others. In this section we seek to identify the determinants of water management reform—first descriptively and then using multivariate analysis.

5.1. *Descriptive analysis*

Our data suggest that the nature of a village's water resources may play an important role in reform. Contrary to common perception, however, it is not villages with the most severe water problems that are reforming. In our survey, we asked about the number of years between 1993 and 1995 (a time before we measured if there was reform or not) in which there was not enough water in canals to satisfy irrigation demands in the village. WUA villages reported on average there were only 0.45 years of water shortages during the three year period, while there were 0.92 years in collectively managed villages (Table 5, row 1, columns 1 and 2). The difference in the degree of water availability was statistically significant. We also asked village leaders directly whether they think water resources in their villages were scarce or not in 1995. Although the differences were not statistically significant, water was also less scarce in WUA villages (row 2). Furthermore, WUAs and contracting seemed to be more likely to appear in villages with access to both surface water and groundwater (row 3).

The finding that reform seems to occur in areas with relatively more available water resources has important implications. It suggests that although water management reform is being encouraged 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, there might be little scope for water savings. Consequently no contractor would be willing to take the contract, as no water savings would mean a lower income.

Descriptive analyses also suggest that the quality or the complexity of the irrigation infrastructure seem to matter in the choice of management form. When a larger share of the canal in a village is lined with concrete, the village's irrigation system seems more likely to remain collectively managed. Specifically, when a village is collectively managed, on average, 22% of the canal system is lined (Table 5, row 4, column 1). In WUA villages it is only 13% and is even lower in contracting villages (4.5%). On average, WUAs and contractors manage longer canals (14 km and 30 km, respectively) than collectively managed systems (6.7 km, row 5, columns 1–3). Hence, leaders appear to be more willing to contract out or turn an irrigation system over to a WUA when the canal system is of poorer quality or more complex. From the contractor's and WUA members' points of view, such an

Table 5 – Characteristics of water resources, canals, village leaders and villages under different water managerial forms in northern China sample villages

	(1) Collective management	(2) Water user association	(3) Contracting	(4) Other institutions[a]
Number of sample villages[b]	111	22	24	7
Characteristics of water resources in the village				
1 Water availability (number of years that there was not enough water in canals between 1993 and 1995)	0.92 (1.24)	0.45** (0.80)	0.73 (1.07)	0.64 (1.18)
2 Village water scarcity indicator variable (1 = water was scarce in the village in 1995, 0 = otherwise)	0.1 (0.30)	0.05 (0.21)	0.04 (0.20)	0 (0.00)
3 Conjunctive use (percentage of land that was conjunctively irrigated by surface water and groundwater in 1995, %)	8.97 (25.13)	12.09 (27.15)	14.38 (33.73)	3.14 (7.47)
Characteristics of canals in the village				
4 Canal lining (percentage of the total length of tertiary canals that was lined in 2004, %)	22.1 (51.17)	13.3 (25.45)	4.56* (3.17)	10.8 (18.55)
5 Canal length (total length of tertiary canals in the village in 2004, km)	6.76 (10.68)	14.25*** (13.82)	30.22*** (65.32)	8.6 (8.71)
6 *Policy dummy* (1 = government promoted water user association or contracting and 0 = otherwise)	0.25 (0.44)	0.77*** (0.43)	0.67*** (0.48)	0.86*** (0.38)
7 *Cropping pattern*: share of sown area in rice in 1995 (%)	21.69 (29.12)	17.36 (29.28)	12.92* (19.30)	16.84 (22.44)
Socioeconomic characteristics of villages				
8 Income per capita in 1995 (Yuan, in log form)	7.04 (0.67)	7.39** (0.37)	7.09 (0.38)	7.34 (0.50)
9 Percentage of migrants (%, share of village labor force that out migrated in 1995)	8.75 (11.08)	11.83 (17.17)	10.36 (13.53)	12.29 (14.67)
10 Percentage of self-business households (%, 1995)	7.45 (9.81)	4.1* (4.23)	3.02** (4.17)	4.75 (6.99)
Characteristics of village leaders				
11 Age of the party secretary (year)	47.86 (7.38)	49.14 (6.15)	46.54 (6.16)	48.14 (3.08)
12 Level of education of party secretary (years of schooling)	9.21 (2.54)	9.36 (2.28)	8.33* (2.58)	9.43 (3.64)
13 Job dummy (1 = the main job of the party secretary was not agriculture in 2004)	0.13 (0.33)	0.14 (0.35)	0** 0.00	0.14 (0.38)
14 Water management experience of the party secretary (years)	5.19 (6.90)	6.91 (6.85)	4.85 (5.46)	5.29 (5.96)
Village demography				
15 Level of education of villagers (%, share of 1995 labor force that had education above high school)	1 (2.71)	2.7*** (4.11)	6.91*** (7.25)	10*** (9.24)
16 Number of household in the village in 2004	444 (376)	461 (178)	429 (167)	389 (201)
Location dummies				
17 Irrigation district location dummy (1 = village located downstream of an irrigation district in 2004 and 0 = otherwise)	0.42 (0.50)	0.5 (0.51)	0.33 (0.48)	0.71* (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 many variations in water management institutions among villages in these two provinces.

Standard deviations of variables are reported in parentheses. Asterisks indicate the difference in the mean of a variable between villages under collective management and villages under other institutions is statistically significant; *Significant at 10%; **Significant at 5%; ***Significant at 1%. *Source of Data*: 2004 NCWRS and CWIM 2001–2004 Panel.

irrigation system might provide more scope for improvement, since there might have been more waste when it was collectively managed.

Consistent with findings in previous analyses on privatization of groundwater (Wang et al., 2005a) and other water reforms, policy appears to play an important role in encouraging water management reform. In 77% of WUA villages and in 67% of contracting villages, provincial officials or irrigation district personnel conducted extension campaigns to encourage water management reforms (Table 5, row 6). In contrast, extension efforts for water management reform were conducted in only 25% of villages that remained collectively managed. The differences in the descriptive statistics were significant.

Other factors appear to be associated with the adoption of WUAs. For example, wealthier villages, those with more migrants, and those with fewer self-employed businesses seem more likely to adopt WUAs (rows 8–10). WUA villages also tended to have older leaders and better educated villagers. These findings are consistent with the idea that it may be not until a village is relatively better off and its members are more active in the off-farm sector that they begin to look for more effective ways to manage water. Alternatively, it might be that residents in such villages are more open to change.

Table 6 – Logit regression explaining factors that contributed to water management institutional reform

	Eq. (1) Dependent variable: reform dummy (=0 if collective management and = 1 if otherwise)[a]	Eq. (2) Dependent variable: water user association dummy (=1 if water user association exists in the village)[b]
Characteristics of water resources in the village		
1 Water availability (number of years that there was not enough water in canals between 1993 and 1995)	−0.555** (2.08)	−0.842* (1.73)
2 Village water scarcity indicator variable (1 = water was scarce in the village in 1995, 0 = otherwise)	0.145 (0.11)	−0.483 (0.41)
3 Conjunctive use (percentage of land that was conjunctively Irrigated by surface water and groundwater in 1995, %)	0.028*** (2.91)	0.031* (1.83)
Characteristics of canals in the village		
4 Canal lining (percentage of the total length of tertiary canals that was lined in 2004, %)	−0.006 (0.67)	0.000 (0.02)
5 Canal length (total length of tertiary canals in the village in 2004, km)	0.050** (2.19)	0.013 (0.84)
6 *Policy dummy* (1 = government promoted water user association or contracting and 0 = otherwise)	1.794*** (2.69)	3.090*** (2.92)
7 *Cropping pattern*: share of sown area in rice in 1995 (%)	0.009 (0.65)	0.052* (1.91)
Socioeconomic characteristics of villages		
8 Income per capita in 1995 (Yuan, in log form)	0.617 (0.95)	3.738*** (2.59)
9 Percentage of migrants (%, share of village labor force that out migrated in 1995)	0.010 (0.47)	0.011 (0.47)
10 Percentage of self-business households (%, 1995)	−0.034 (0.81)	−0.056 (0.76)
Characteristics of village leaders		
11 Age of the party secretary (year)	0.050 (1.26)	0.149* (1.83)
12 Level of education of party secretary (years of schooling)	0.016 (0.15)	−0.068 (0.35)
13 Job dummy (1 = the main job of the party secretary was not agriculture in 2004)	−0.309 (0.33)	1.446 (1.11)
14 Years of water management experience of the party secretary	0.033 (0.74)	0.003 (0.04)
Village demography		
15 Level of education of villagers (%, share of 1995 labor force that had education above high school)	0.153** (1.96)	0.058 (0.64)
16 Number of household in the village in 2004	0.000 (0.03)	0.000 (0.18)
Location dummies		
17 Irrigation district location dummy (1 = village located downstream of an irrigation district in 2004 and 0 = otherwise)	−0.343 (0.61)	−0.013 (0.01)
18 Constant	−9.760** (2.08)	−36.658*** (3.19)
19 Observations[c]	160	137

[a] Non-collective management includes WUA and contracting.
[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 not many variations in water management institutions among villages in these two provinces. Shanxi Province is excluded in Eq. (2) since it does not have any WUA villages.
Absolute value of *z* statistics in parentheses, *significant at 10%; **significant at 5%; ***significant at 1%. *Source of Data*: 2004 NCWRS and 2001–2004 CWIM Pane.

5.2. *Multivariate analyses*

In this section we conduct two regressions. First, we seek to identify the factors that have contributed to institutional reforms. The model for the first regression is:

$$\mathrm{INST_v} = \alpha + \sum_{i=1}^{8} \mathbf{X}'_{iv}\beta_i + \sum_{k=1}^{4} \mathbf{D}_k\delta_k + \varepsilon_v \quad (1)$$

The dependent variable, $\mathrm{INST_v}$, is a dummy variable that equals one if the village has adopted either a WUA or contracting to manage water. The subscript 'v' is the index for the sample villages. The reform dummy variable will be explained by the variables examined in the descriptive analysis, including measures of the nature of water resources ($\mathbf{X}_1$, bold letters denotes a vector of variables), the characteristics of the canal ($\mathbf{X}_2$), government policy ($\mathbf{X}_3$), cropping pattern ($\mathbf{X}_4$), socioeconomic characteristics of the village ($\mathbf{X}_5$), characteristics of village leader ($\mathbf{X}_6$), village demography ($\mathbf{X}_7$) and locational factors ($\mathbf{X}_8$). We also added a set of province dummy variables, $\mathbf{D}_k$s, where k is the index for the sample provinces. One province dummy is dropped to avoid perfect collinearity in estimation. Because the dependent variable is a limited dependent variable (either 1 or 0), we use a logit regression

to estimate the parameter associated with these explanatory variables, $\boldsymbol{\beta}_i$s and $\boldsymbol{\delta}_k$s.

The second regression uses the same explanatory variables as in Eq. (1) except for the dependent variable, WUA_v, which is a dummy that equals one if the village adopted WUA and zero otherwise. The model for the second regression is:

$$WUA_v = \alpha + \sum_{i=1}^{8} \mathbf{X}'_{iv}\beta_i + \sum_{k=1}^{4} \mathbf{D}_k\delta_k + \varepsilon_v \quad (2)$$

5.2.1. *Results from model 1: determinants of water management reform*

The multivariate analysis generates results similar to those from the descriptive analyses. For example, the results of Eq. (1) suggest that, ceteris paribus, villages that were relatively water abundant were more likely to reform (or adopted non-collective forms of irrigation management). Specifically, during the three year period, if a village suffered more years without enough water in their canals, the tendency was to *not reform* (Table 6, row 1, column 1). When villages had conjunctive water resources in 1995 (which might be interpreted as having relatively more abundant resources, ceteris paribus), reform is also more likely (row 3). Although water management reforms are spreading, our results demonstrate that reforms tend to occur in areas with more available water resources rather than areas in crisis. Leaders and farmers in these villages might not want to change in fear of making a current water crisis even worse, which might happen in the case of experimenting with a new managerial form. In addition, there might be no obvious benefit of change where water resources are so scarce and irrigation systems are relatively small. Clearly, if policy makers want to use water management reform to help solve China's water crises in water-short areas, something additional will be required.

Also consistent with the descriptive analyses, villages appear to reform water management when they have larger and more complex systems. The positive and significant coefficient on canal length means that villages with longer canal systems have a greater propensity to reform (row 5). These findings are consistent with those in Huang et al. (2008b) that WUAs and contracting are more likely to be chosen in villages with more complex canal systems. In such systems, managing the canal system is a labor intensive and management intensive task that requires a manager with substantial motivation, which incentives or a participatory body could generate.

In addition, the estimated coefficient for the policy dummy variable is positive, large in magnitude and statistically significant (row 6, column 1), even though we have included a set of provincial dummies that capture any province level effects. This suggests that much of the policy effect is sub-provincial at the county level or the township level. There is enough heterogeneity within each province that when WUAs and contracting are promoted in some villages, but not in others, there is a different rate of response within the province.

Several of the other control variables also are of interest. For example, while the coefficient on the income variable is positive, it is not statistically significant (row 8). Only the level of education of villagers is statistically significant (row 15). Perhaps villages with higher levels of education are more willing to reform—because they are more flexible or because they think WUA or contracting could provide them with more benefits of some sort. Education could also be correlated with several other factors, such as a better pool of candidates for contractors or WUA managers.

5.2.2. *Results from model 2: determinants of WUAs*

The signs, magnitudes and levels of statistical significance for many of the estimated coefficients for Eq. (2) are similar to those of Eq. (1) (Table 6). As in the case of general water management reform, villages with relatively more water available in 1995 (row 1, column 2) and those with conjunctive water resources (row 3) were more likely to form WUAs. Similarly, policy also plays a positive role in promoting WUAs (row 6).

There are two estimated coefficients in the WUA regression (Eq. (2)) that are different from the results obtained for Eq. (1). The positive and significant coefficients on the income per capita variable and the age of the party secretary variable suggest that WUAs have emerged in villages that were relatively well off or villages with leaders that have more experience (rows 8 and 11). WUAs are either easier for such villages to organize or WUAs might be in greater demand in such villages.

6. Conclusions

We have documented the evolution of existing and new water management institutional forms over time and across provinces. By 2004 more than one-quarter of our sample villages in northern China had replaced collective management with either Water User Associations (WUAs) or contracting. When the reform took place, there was a shift of responsibility from the collective leadership to either the WUA board or the contractor. The reform-oriented institutions have some features that lead to better water management. For example, more than 70% of the contractors face economic incentives that link their earnings with the quality of irrigation services they provide. Almost half of the WUAs manage irrigation systems in a transparent way, such that board members share management information with users. However, some aspects also call for improvement. Only a small portion of the WUAs are provided any incentives to improve water management. There is little participation by farmers in any of the management activities, even in villages with WUAs, and many WUAs have close ties to the village leadership. Policy makers seeking to deepen reform efforts in China should focus on providing incentives and increasing farmers' participation.

We have also endeavored to explain why some villages have chosen to retain collective management, while others have decided to form WUAs or engage in contracting. At least three implications are evident. First, locality matters. Regression results show that villages are more likely to reform when water is relatively abundant and when the village canal network is relatively large. Hence, in China's future design of water management reforms, policy makers should consider

the local conditions of villages and be aware that not one reform path fits all villages. Second, local governments play important roles. When the county level or the township level governments promoted either WUA or contracting, most villages reformed. Thus, policy makers should continue to rely on local governments to move the reform in a direction that can address China's water problems faster and better. Third and probably most significantly, water management reform alone is not adequate to address China's water scarcity problems. Institutional reform has not occurred in the most water scarce parts of China. If the main policy goal is to save water, policy makers must look beyond water management reform. A more comprehensive strategy, which combines water management reform with other complementary policies (such as water pricing), may be more effective.

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