AGRICULTURAL ECONOMICS

Agricultural Economics 34 (2006) 315–330

Incentives to managers or participation of farmers in China's irrigation systems: which matters most for water savings, farmer income, and poverty?

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Received 16 September 2003; received in revised form 22 November 2004; accepted 5 April 2005

Abstract

The overall goal of our article is to better understand which matters for water savings, farmer income and poverty in China's irrigation systems: incentives to managers or participation of farmers. To pursue this goal, the article has three objectives. First, we track the evolution of water management reform, examining the practice of providing incentives to managers, and increasing the participation of farmers. Second, we identify the impact of water management reform on crop water use. Specifically, we want to measure whether or not incentives to managers and farmer participation in water management institutions affect the performance of the irrigation system. Because we also are interested in the potential results of water management reform, the article explores how changes in incentives and farmer participation affect farmer income and poverty. Based on a random sample of 51 villages and 189 farmers in four large irrigation districts in Ningxia and Henan provinces, both in China's Yellow River Basin, our results show that the two major forms of water management reform, water users' associations (WUAs) and contracting, have begun to systematically replace traditional forms of collective management. Our analysis demonstrates, however, that it is not the nominal implementation of the reform that matters, but rather it is the creation of new management institutions that offer water managers monetary incentives that lead to water savings. In contrast to the original design of China's reform policies, participation of farmers has not played a role in saving water. Importantly, given China's concerns about national food production and poverty alleviation, the reductions in water, at least in our sample sites, do not lead to reductions in income and do not increase the incidence of poverty.

JEL classification: Q25, Q28

Keywords: Water management reform; Incentives; Participation; Water savings; Poverty

1. Introduction

Over the past two decades, many nations have attempted to reform water management by decentralizing water management responsibilities in order to improve the performance of irrigation systems (Johnson et al., 1995; Meinzen-Dick et al., 2002). After experiencing the rapid development of irrigation initiated during the post-World War II era, since the early 1980s governments have had to deal with a number of difficult water control issues, such as the deterioration of infrastructure, the decline of irrigated area, inefficient water use, and a fall in agricultural productivity (World Bank, 1993). Increasing financial pressure and inefficient management have been identified as two of the major sources of the problems (Sagardoy, 1995; Tang, 1992). In response, many governments have transferred management responsibilities to local water managers. In order to improve the performance of the irrigation systems, irrigation officials have offered incentives to water managers and encouraged the participation of farmers in system management (Bandaragoda and Memon, 1997; Merrey, 1996; World Bank, 1993).

Because of the difficulties in the implementation of other policies to combat China's growing water crisis, like other countries in the world, policymakers in China have turned to water management reform. Both the poor performance of irrigation systems and increasing water scarcity threaten the long-run development of the agricultural economy in parts of China (Ministry of Water Resources and National Planning Commission, 1999; World Bank, 1998). China's government has identified the nation's rising water scarcity as one of the key problems that must be solved if the nation is to meet its national development plan in the coming years (Zhang, 2001). Unfortunately,

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many traditional methods (such as increasing water supply and extending new water-saving technologies) seem to have failed to solve the nation's water problems (Lohmar et al., 2003). In order to address these issues, leaders in China have encouraged local governments to reform water management by decentralizing many management functions (Nian, 2001; Reidinger, 2002). One of the major objectives of reforming water management in China is to improve water-use efficiency. 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 (Xu, 2001). Inefficient water use has increased water scarcity.

In China's version of water management reform, officials have mostly focused on promoting either water users' associations (WUA) or contracting. According to the initial design of the policies, WUA are farmer-run, participatory institutions that are created to take the place of traditional, village leader-run water control organizations. Alternatively, reformers sometimes encourage villages to contract the management responsibilities of the village-level irrigation system to an individual who can earn a profit if water is saved.

While there have been some successes, not all water management reforms—either inside or outside China—have been implemented successfully. The literature has documented many successes in water management reform internationally. For example, water management reforms in Mexico, Turkey, Colombia, and the Philippines have been considered as successful cases (Groenfeldt and Svendsen, 2000). However, there are many cases of water management reform that have failed (Easter and Hearne, 1993; Groenfeldt and Svendsen, 2000; Vermillion, 1997). Like similar attempts in other countries, the record in China seems to be mixed, although most evaluations are only based on anecdotes or case studies (China Irrigation Association, 2002; Huang, 2001; Nian, 2001). Although success in implementing pilot water management reform programs has led to calls for their expansion nationwide, effective implementation of the reform has been difficult (Ma, 2001; Management Authority of Shaoshan Irrigation District, 2002). Visits to the field can easily uncover cases in which local water management reforms were implemented and failed.

Although the literature argues that the success of water management reform depends on both incentives and the participation of farmers, in the writing of individual scholars who evaluate the performance of water management reform, some typically stress one or the other: either the importance of providing good incentives or participation. Some writers examining irrigation systems outside China have proposed that water management reform can succeed only if it has the active participation of local farmers (Groenfeldt and Svendsen, 2000; Ostrum, 1992; Raby, 1997; Svendsen and Knight, 1996). For example, many observers believe that Mexico's irrigation management reforms have succeeded as a consequence of active participation by farmers (Groenfeldt and Svendsen, 2000). While there is less empirical work, the literature also discusses the importance of providing good incentives to water managers (Merrey, 1996; World Bank, 1993).

In China there is also an implicit debate. Some agencies, such as the World Bank (Reidinger, 2002) and part of China's researchers (Nian, 2001), believe that participation is of primary importance as they have tried to incorporate participation components into their projects. When China implements reforms in other areas (outside of water management), reformers frequently give high priority to using incentives to encourage behavior that will push forward the new policies (Park and Rozelle, 1998). Certainly, as water management reform begins to become more widespread, policymakers have to decide whether they should put more emphasis on providing incentives or on encouraging participation, or both.

The overall goal of this article is to better understand what matters most for water management reform in China: incentives to managers or participation of farmers.[1] To pursue this goal, the article has three objectives. First, we track the evolution of water management reform, examining the practices of providing incentives to managers, and encouraging the participation of farmers. Second, we identify the impact of water management reform on crop water use, focusing mainly on the role that incentives to managers and participation of farmers can play in facilitating water savings. Because we are interested in the potential results of water management reform, the article also explores how changes in incentives and participation affect income and poverty.

2. Data

The data for our study come from a survey that we conducted in 51 villages in four irrigation districts (IDs) in Ningxia and Henan provinces. To increase the variation among regions, we chose our provinces to be located in the upper (Ningxia) and lower reaches (Henan) of the Yellow River Basin (YRB). The four sample IDs are typical of irrigation systems along the Yellow River; each of the sample IDs belongs to a class of large-scale irrigation districts. In selecting the IDs for our study, we considered a number of criteria. From a number of IDs in each province, we chose two IDs based mostly on water availability by selecting one that is upstream in the province and one that is downstream. After the IDs were selected, we randomly chose sample villages from a census of villages in the upper, middle, and lower reaches of the canal network within the IDs.[2] Enumerators also randomly chose four households

[1] Although at times we analyze incentives and participation separately, we recognize that in many cases, incentives to managers and farmer participation are not mutually exclusive. It is possible that rather than saying whether one is more important than the other, it may be more important to say that both are needed.

[2] The two IDs in Ningxia Province are Weining Irrigation District (WID-N) and Qingtongxia Irrigation District (QID-N). The IDs in Henan Province are People's Victory Irrigation District (PID-H) and Liuyuankou Irrigation District (LID-H).

within each village. In total we surveyed 51 village leaders, 56 water managers, and 189 farm households.

While located in different parts of China, the organizational structures of the canal systems in each ID are similar. Each ID has a set of main canals that take water directly out of the Yellow River. Officials from the ID, depending on their allocations from the YRB Commission, make up a water allocation plan for each village. In almost all of our IDs, there is a metered gate that supplies water to each village. This makes a village a more or less independent agent of the ID. Such villages are typical of villages in North China that are next to or near the Yellow River. The canal network in the village, then, is completely maintained by the village and all of the water that flows into the village is for the exclusive use of the village's own residents (and does not have to be shared with villages either upstream or downstream of it). In each village there is a person—whether leader or appointed water manager—who is responsible for coordinating water deliveries from the IDs and remittances of water fees from the village. For this reason, we are able to analyze the village, its water manager, and water use as an independent unit.

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 the survey three types of water management institutions were identified: collective management, WUAs, and contracting. In the village and canal management questionnaires we recorded the share of canals within the village that is controlled by each management type for each of 3 years (1990, 1995, and 2001). In addition, enumerators also asked how managers were compensated. When managers have partial or full claim on the earnings of the water management activities (for example, on the value of the water saved by water management reform), we say that they face strong incentives (or that the manager is managing *with incentives*). If the income from their water management duties is not linked to water savings, they are said to manage *without incentives*.

Regardless of which management type a village chooses, we also asked the village leaders and canal managers whether farmers participated in any one of three aspects of the creation and/or operation and maintenance of the local water management system. Specifically, enumerators asked canal managers whether or not farmers were consulted about the establishment of WUAs. The survey also collected information on the extent of the participation of farmers in the selection of canal managers. Finally, we asked whether or not farmers were invited to attend regular meetings of the WUAs.

The survey form also addressed the degree of transparency under which business in the village irrigation organizations took place. The idea is that it is essential that irrigation organizations be accountable to water users—a characteristic that can have a separate effect from incentives and participation. One of the ways in which managers are accountable to water users is to be willing to share information with users on different issues that affect the operation and financial management of the irrigation organizations. Such information could be about elements such as: (a) the way in which the water fee is generated; (b) the volume of water that was supplied to the village; and (c) the actual irrigated area. Therefore, using information on these three dimensions of transparency, we have created an indicator of the degree of transparency that is being practiced in the village's irrigation management.

The survey contained a set of questions that we use to develop several measures of the effects of water management reform—water use, income, and poverty. In order to get relatively accurate measures of water use, which is typically difficult to elicit in surface water systems, we adopted the strategy to ask all those who 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, the number of hours per irrigation, and the average depth of the water that was applied to the field. With this information, we were able to combine the various measures into a single measure on which we develop our final estimates of water use (see the Appendix).[3]

We also systematically collected information on household income from our farmer survey 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 those from cropping, livestock, off-farm wage labor, earnings from the family's business enterprise, and other miscellaneous sources. 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 includes the household head, the household head's spouse, and all individuals who lived in the household for at least 3 months per year) with the national poverty line (625 Yuan per capita per year in 2001).[4]

The rest of our survey instrument asked for information about a number of other important variables that we believe affect either water management institutions or outcomes or both. For example, we asked village leaders and water managers if upper-level government officials took steps to encourage the extension of water management reform in their villages. A number of other questions asked about the degree of water scarcity, the level of investment in the village's irrigation system over the past 20 years, as well as a number of other village, household, and

[3] It is possible that water savings could have been generated by reducing irrigated area. However, in our study areas, after the water management reforms, the ratio of total cultivated area in the village that was actually serviced by the irrigation system almost did not change. According to our data, officials in 22 villages implemented management reforms. In 21 of them, there was no change. There was only a reduction of irrigated area in one village, and the reduction was only minimal (10%). In addition, based on our survey of local leaders, water managers, and farmers, water savings mainly came from the improvement of water delivery efficiency. Given this situation, we are able in the context of our study in China to use "water use per hectare" as a measure of management efficiency.

[4] While our definition of poverty in this study is based on measured income per capita, we realize that poverty alleviation is actually a much more complicated process, and includes an entire range of policies, such as, land reform, education, etc.

plot characteristics. Descriptive statistics of the study's main variables are shown in Table A.1.

3. Incentives to managers and participation of farmers

Based on our field surveys, after upper-level officials began implementing the reforms, surface water is being managed in three different 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 distributed water in most of China's villages during the People's Republic period.[5] A WUA is a farmer-based, participatory organization that is set up to manage the village's irrigation water. In a WUA, a member-elected board is supposed to be assigned the control rights over the village's canal network and the water that is delivered through it. *Contracting* is a system in which the village leadership establishes a contract with an individual to manage the village's canal networks in return for a payment to the individual.

According to our data, since the early 1990s, and especially after 1995, reformers have established WUAs and contracting in the place of collective management. The share of collective management declined from 91% in 1990 to 64% in 2001. Contracting has developed more rapidly than WUAs. By 2001, 22% of villages managed their water under contracting and 14% through WUAs. Assuming that the results from our sample reflect general trends across Northern China, the somewhat more rapid emergence of contracting may be due to the ease of setting the system up and the similarities of contracting to the other economic reforms that have unfolded in rural China (Nyberg and Rozelle, 1999).[6]

While there has been a shift from collective management to WUAs and contracting during the past 5 years, water management reform still varies across the four sample IDs. WUAs and contracting have developed more rapidly in Ningxia than Henan. For example, by 2001 the collectively managed water in only 27% of the sample villages in the WID-N of Ningxia Province. WUAs managed water in about 23% of the villages and contractors managed water in approximately 50% of them. In Ningxia's other ID (QID-N), the share of villages under WUAs and contracting reached 49%, almost the same as those under collective management. In contrast, significantly less reform occurred in Henan. Only 8% of the villages in the one of the Henan's IDs and none in the other had shifted management duties to either contracting or WUAs.

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, the dramatic differences between Ningxia and Henan Provinces suggest that upper-level government policy may be playing an important role. 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. The sharp shift away from collective management is consistent with an interpretation that these measures were effective in pushing reform (or at least relaxed the constraints that were holding back reform).

3.1. Incentives to water managers

While the shift in China's water management institutions demonstrates that the nation's communities are following policy directives that are being developed and issued by upper-level governments, at the local level practice often varies from theory. An examination of the ways in which managers are compensated perhaps shows the greatest difference between theory and practice. To demonstrate this, however, we need to understand how farmers pay fees, how managers are compensated, and how IDs are paid for the water that is delivered to a village.[7] In implementing water management reform ID officials agree that the water manager only has to pay the per cubic meter charge for the water that is actually used. If the *actual quantity* of water delivered to the village (at the request of the water manager) is less than the *targeted quantity* (an amount set by the ID based on historic water use and water availability), the difference is the water savings generated by the manager. The manager who generates water savings can earn a profit (called *excess profits*) because he earns the difference between the fee that is collected from the farmers (based on the targeted quantity) and the payment that is made for the actual quantity of water that is ordered by the manager and delivered by the ID to the village. In communities that give the water manager full incentives, the excess profit is the amount that is earned by the manager.[8]

[5] In our study areas, the village committee plays the role of the "Village Irrigation Management Group." These organizations manage water largely without the participation of farmers.

[6] During China's economic reforms, many government services have been contracted out to private individuals, including grain procurement, extension, and health services.

[7] It is true that as early as the 1980s, in order to improve water use efficiency, China's government began to encourage local governments to adopt volumetric water pricing approaches (Ministry of Water Resources, 2002). However, due to the high transaction costs that are often associated with introducing these programs, these types of measure have rarely been implemented; especially at the farm gate, there is little volumetric pricing. Instead, sales-by-volume programs, when implemented, have been done at the village level. For this reason, the village is the focus of our study.

[8] In the main text, we only discuss incentives to managers in the local ID. In fact, downstream users benefit most from water savings. While this is good for the basin (nation) as a whole, it does not explain the incentives for others in the village (leaders and farmers) to save water. Village leaders have an incentive to save if they are administratively instructed to do so; it is part of their job. Unfortunately, because they are busy and it is difficult to monitor the actions of village leaders, even if they say they are trying to conserve water it is unclear if they actually are or not. That is why incentives are needed. The case of farmers

According to our data, there are sharp differences in the ways in which villages have implemented the incentive part of the reform packages, regardless of whether or not the village's irrigation system is run as a WUA or contracting system. For example, in 2001, on average, leaders in only 41% of villages offered WUA and contracting (or *noncollective*) managers with incentives that could be expected to induce managers to exert effort to save water in order to earn an excess profit. In the rest of the villages, although there was a nominal shift in the institution type (that is, leaders claimed that they were implementing WUAs or contracting), in fact, from an incentive point of view, the WUA and contracting managers were operating without imposed incentives. In these villages managers are similar to leaders in a collectively managed village in that they do not have a financial incentive to save water. The incentives offered to the managers also differ across IDs. Hence, to the extent that the incentives are an important part of water management reform, the differences across time and space mean that it would not be surprising if the managers in some villages were more effective at saving water than the managers in others.[9]

3.2. *Participation of farmers*

The focus on participation within the field of irrigation management has emerged from a concern about the effectiveness of management. The question that participation addresses is "Who is best suited to carry out which management functions?" (Vermillion and Sagardoy, 1999). Those in favor of participation believe that farmers should decide on the roles that they would like to perform and the roles that they want managers and their leaders to perform. Participation can involve all aspects of irrigation; from whether or not the irrigation system should use farmer participation to who will head it and how it will run.

In our survey we attempt 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 of decision making cover most major activities of water management institutions (their creation; leader selection; 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.

Table 1
Farmer's participation and incentives provided to farmers in WUAs in sample irrigation districts (IDs) in Ningxia Province, China, 2001

	Percentage of samples (%)		
	WID-N (Weining)	QID-N (Qingtongxia)	Whole sample
Farmer's participation			
Decision on the establishment of WUA	0	25	12.5
Decision on selecting managers	25	25	25
Regular meetings	0	50	25
Above any activity	25	50	37.5

Source: Authors' survey.

In contrast, the reforms that led to the creation of WUAs explicitly attempt to encourage farmer participation. Again, however, practice often varies from theory. In our 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 observe because this type of management is so new in our sample villages), our data show that on average only about 13% of WUAs involve farmers in the decision on their establishment (Table 1, row 1 and column 3). In fact, most farmers (70%) who 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.[10]

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% of WUAs allow farmers to participate in the process of selecting managers (Table 1, row 2). As a result, in most cases (70% of the WUAs), the governing board of

is a bit different because there is no way to volumetrically measure water to farmer fields, a reform package that wants their support must be at least as good as the original system. To do so, what typically happens is that water fees are reduced somewhat to ensure that farmers believe there is some benefit and not resist.

[9] In our study sites, we have never encountered "rent seeking." Although this is an important issue in some countries, few scholars have discussed this as an important issue in China. That is not to say that it does not occur. Corruption is also difficult to study. Therefore, we ignore the issue of rent seeking in China's water management system.

[10] Although the meaning of farmer participation in China is similar to that in other international venues, this does not mean that China's farmers are being empowered by WUA. We are only describing the extent of farmer participation. To the extent that farmer participation does not affect performance, we are unable to say if that is because the extent of participation is insufficient or if it does not inherently (for whatever reason) affect behavior.

the WUA is the village leadership itself. In a minority of the cases (30% 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 with the village leadership (for example, the manager frequently is a former village leader or a close relative of the current leader). Moreover, although 80% of WUAs hold regular meetings, farmers are invited to participate only in 25% of them.

3.3. Accountability

Compared with collective management and contracting, 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% of WUAs shared all three types of information about the irrigation system with farmers (in other words, the WUA told farmers how water fees are generated, what volume of water was actually delivered by the ID to the village, and the actual area that was irrigated). About 50% of WUAs shared two of the three types of information. The rest (about 10%) shared at least one type with farmers. In contrast, neither collective managers nor contractors shared any of this information with farmers.

4. Water management reform and crop water use

Although it is possible that water managers may use methods of water management that would save water at the expense of farmers, most managers (typically under the scrutiny of village leaders) developed new ways of managing water that increased water use efficiency without having a systematically negative effect on production or incomes.[11] In particular, based on our field survey, irrigation managers took actions to save water in a number of ways. They both improved the operation of the system (by supervising water delivery more intensively and using new techniques), and they increased canal maintenance. For example, in the study regions rice is one of most important crops. In local irrigation systems using traditional leader-run management regimes, leaders often used a system in which there was continuous flooding of the fields during long periods of time during the season. Obviously, such a system is less supervision intensive because the only time the official needs to spend on management is the few minutes that it takes to open a few gates in the canal network when there is water in the main canals from the ID. After opening the gate, they can essentially forget about their management duties. In such a system, much water flows through the village's canal system and directly into the outflow ditches.

However, in some reformed regions (in many cases under the direction of local extension agents), local canal managers adopted a system of irrigation called "alternate wetting and drying irrigation." In this system, after the irrigation canals are used to flood the fields, they are closed again until the soil begins to dry out. At this point, the fields are then flooded again. Of course, to do this properly takes a lot more supervision time as the water deliveries are on again and off again and need more precise timing. According to a joint study by the International Water Management Institute, the International Rice Research Institute, and Wuhan University's Hydrology Department, alternate wetting and drying irrigation generates water savings of up to 30% in terms of field deliveries (Barker et al., 2001). Our surveys also identified a number of other ways in which managers saved water: "Water rotation" irrigation (instead of flooding the entire village through a single outlet); "timed released" irrigation (a system that more carefully times the opening and closing of irrigation inlets and outlets); and improved canal maintenance that is implemented by lateral de-silting and keeping the canal network inside the village free of debris and plant matter.[12]

Of course, according to self-reported management efforts we cannot rule out that part of the water savings did not come from unilateral reductions in water deliveries by canal managers (despite the fact that canal managers were not supposed to do so, by the terms of the contract). To examine this issue, we asked farmers about timing of the deliveries of irrigation water during the sample year and the impact that delayed deliveries (if any) had on their crop output. In response to these questions we found that, although in our sample farmers did experience delays in irrigation that caused reduction in yields, such timing problems were not significantly related to the fact that an irrigation system's manager had an incentive or not (the correlation coefficient between incentives and delays only is 0.09 and insignificant from zero). In addition, although we found that the share of irrigation delay on plots managed by those with incentives is somewhat higher than those without incentives,

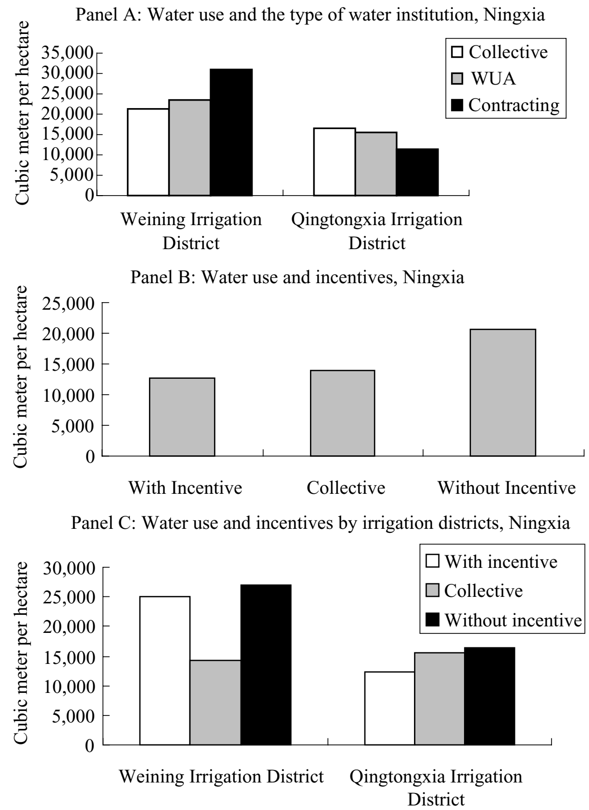
[11] Field level delivery savings (the type of savings that we are talking about here) will not automatically lead to true basin-wide savings. It is possible that water lost during delivery and on the fields could help recharge underground aquifers. However, because there is so little groundwater used in our IDs this is not really an issue. It also is possible that if all of the water that was used on the fields prior to reform went into the groundwater and flowed back into the river, there would be really no true savings. While the share of groundwater that is "wasted" during delivery to the field in some parts of the Yellow River system may flow back into the river, in other parts (e.g., in Inner Mongolia, Shaanxi and Henan) there are sinks and areas in which the river bed is above the area being irrigated. In China's dry, hot and windy areas along most parts of the Yellow River, over-irrigation could lead to significant amounts of evaporation. Hence, although we do not know for sure (and cannot find any hydrologists that knows for certain), it seems that in this case, reducing field deliveries could be also leading to true water savings.

[12] It should be noted that in addition to water management reforms, there were other ways in which water savings were occurring. In particular, farmers in the study villages adopted water saving technologies. For example, farmers used border irrigation on 19% of the sown area. They leveled their fields in the case of 79% of the sown area. Surface pipes/hoses were used on 12% of the sown area. Canals were lined for 6% of the sown area and 6% of farmers adopted drought-resistance varieties.

it is not significantly so. The reasons for the delays are also different between plots run by managers facing different types of incentives. For example, most irrigation delays under the management without incentive are related to poor management and low rates of payment of the village's water fee to the ID (Table 2). In contrast, most delays on plots managed by irrigation managers that face incentives are due to the fact that water scarcities kept water from being delivered to the ID.

Assuming that water savings is mainly coming from efficiency-enhancing actions taken by managers, we can examine the impacts of institutional forms and their organization on water use. Our data show that, whereas water use in some areas that have established WUAs and contracting is lower than in those areas still under collective management, it is higher in others (Fig. 1, Panel A). For example, in QID-N in Ningxia the water use per hectare in areas that have shifted to WUAs or contracting is lower than in those areas in which the collective still manages the water. However, in Ningxia's other ID (WID-N), water use per hectare is higher in those villages that have shifted to WUAs or contracting.

While the effectiveness of changing from collective to non-collective management in terms of water saving is not clear, our data show the importance of policy implementation. In particular, the importance of incentives in making the reforms work is shown when comparing water use in those villages that provide their water managers with incentives with those that do not, both across the entire sample and in the individual IDs (Fig. 1, Panels B and C). After reform, when managers face incentives to earn profits by saving water, water use per hectare falls by nearly 40% when compared to those managers without incentives across our Ningxia sample (Panel B).



Source: Authors' survey.

Fig. 1. Water use and the types of water institutions and incentives, 2001.

Table 2
Irrigation delays and reasons for delays by various types of incentive mechanisms in China's surface water irrigation management institutions, 2001

	Nature of managerial incentives	
	With incentive	Without incentive
Irrigation delays[a]		
All sample plots	74	294
No irrigation delays (%)[b]	72	81
Yield reductions due to irrigation delays (%)[c]	14	14
Reasons for irrigation delays[d]		
No water in canals due to dry weather (%)	35	9
Poor management (%)	65	73
Late payment of water fees, ID does not allocate water to village's canals (%)	0	18

[a]Irrigation delays are reports by farmers that because irrigation water was not available at times when it was need, the crop suffered damage.
[b]No irrigation delays represents the share of plots of farmers in the sample that did not suffer any irrigation delay.
[c]Yield reductions due to irrigation delays measures for plots that suffered irrigation delays an estimated of delay-related yield falls.
[d]Rows 4 to 6 in each column add to 100%.
Source: Authors' survey.

Looked at in another way, however, our descriptive data are a bit more ambiguous in establishing the relationship between water management reform and water use. Part of Panel C supports the previous descriptive findings. It shows that water use is lower in both IDs in villages that have managers with incentives when compared to villages with managers without incentives provided that they have experienced water management reform—that is, they have implemented WAU or contracting. However, when water use by managers in reformed villages (both those with and without incentives) is compared with water use in villages that are still run by traditional, collectively managed village irrigation systems (unreformed villages), there is a less consistent pattern.

Although the positive relationship between incentives and water use is mostly supported by the descriptive statistics, the story is different when examining the relationship between participation and water use. The data show that in villages in which farmers participate in water management, water use is not lower (Table 3, columns 1 and 2, rows 7 and 8). Specifically, if the management of WUAs allows farmers to participate in some way, the point estimate of crop water use is actually higher than

Table 3
Relationship between incentives to managers, farmer's participation, and crop water use in sample irrigation districts (IDs) in Ningxia Province, 2001

	Crop water use		
	(1) With participation	(2) Without participation	(3) Test of difference in means (column 1 vs. column 2)[a]
Measure of farmer's participation	(cubic meters per hectare)		
(1) Decision on the establishment of WUA			
QID-N (Qingtongxia)	22,668	15,207	0.61
(2) Decision on selection of managers			
WID-N (Weining)	24,641	14,955	0.39
QID-N (Qingtongxia)	26,614	25,133	0.61
(3) Attendance at regular meetings			
QID-N (Qingtongxia)	16,108	15,337	0.36
(4) Any of above activities in (1), (2), or (3)			
WID-N (Weining)	19,928	15,083	0.39
QID-N (Qingtongxia)	26,614	25,133	0.36

[a]Column (3) is the *t*-statistic for the difference between columns 1 and 2. None are significantly different at standard levels of confidence.
Source: Authors' survey.

the point estimate of those villages in which farmers do not participate. Statistical tests of the difference between the means of villages with and without participation demonstrate that there is no significant difference (column 3). Our data also show that there are no statistical differences between those villages that allow farmers to participate in specific types of activities (for example: the decision to establish the WUA—rows 1 and 2; the decision to select managers—rows 3 and 4; and the encouragement by managers for farmers to attend regular meetings—rows 5 and 6).

While our descriptive analysis shows that there is a positive relationship between incentives and water savings, and that there is no apparent relationship between participation and water savings, in fact, it is possible that there are other factors that are associated with incentives and participation that are creating the observed correlations (or lack thereof). In particular, it may be that the cropping structure, the value of investment into the canal system's infrastructure, the scarcity of water, and the nature of the irrigations accountability to villages may affect incentives, participation, and water use (Fujita et al., 2001; Meinzen-Dick et al., 2002). Due to these other factors, multivariate analysis may be more effective when analyzing the relationship between the type of water management institutions, incentives, participation, water use, and other outcomes.

4.1. Multivariate empirical model and results

Based on the above discussions, the link between water use per hectare and its determinants can be represented by the following equations:

$$w_{jk} = \alpha + \beta M_k + \delta Z_{jk} + D_{jk} + \varepsilon_{jk}, \tag{1}$$

$$w_{jk} = \alpha + \beta I_k + \gamma F_k + \delta Z_{jk} + D_{jk} + \varepsilon_{jk}, \tag{2}$$

where w_{jk} represents average water use per hectare for household *j* in village *k*. The rest of the variables in Eqs. (1) and (2) are those that explain water use: M_k measures the type of the water management institution (such as WUAs and contracting); I_k and F_k, our variables of interest, separately measure the nature of incentives and participation of farmers; and Z_{jk} is a matrix of control variables, representing the degree of transparency and other village and household factors that affect water use.[13] Specifically, we include a number of variables to hold constant the nature of the village's production environment and its cropping structure. We include variables that measure the source of water (either surface or ground), the degree of water scarcity, and the level of irrigation investment per hectare (a stock variable estimated as the sum of the investments made over the past 20 years).[14] Cropping structure is measured as the proportion of the village's sown area that is in rice in 1995. Household characteristics include age and education of the household head and farm size. Finally, our model also includes D_{jk}, a dummy variable representing the ID that serves the household. The symbols α, β, γ, and δ are parameters to be estimated and ε_{jk} is the error term that is assumed to be uncorrelated with the other

[13] With our survey data, we also have created an indicator variable measuring the degree of transparency that is being practiced in the management district. If all three pieces of information are shared between managers and water users, we give the transparency variable a value of 1; if there are only two elements, then the value is 0.66; if only one, the value is 0.33; and 0 otherwise. With this variable, our survey results show that the degree of transparency of WUA is higher than that of collectives or contracting.

[14] The degree of water scarcity is an indicator variable developed from a question included in the village questionnaire. Enumerators asked village leaders to characterize the nature of water resources in their village. The leaders chose one of three precoded answers: 1 = water is very scarce; 2 = water is relatively scarce and frequently constrains agricultural production; and 3 = water is not scarce (at least currently). The indicator variable takes on the value of one if the leader responded either 1 or 2, and zero if he responded 3.

Table 4
Regression analysis of determinants of crop water use at household level

	Water use per hectare			
	OLS	OLS	IV	IV
Water management institutions				
Type of institution				
Share of WUA	−1,311		−1,920	
	(0.70)		(1.00)	
Share of contracting	−704		−2,469	
	(0.49)		(1.34)	
Incentive				
Share of noncollective with incentives to managers[a]		−2,637		−6,166
		(1.76)*		(1.82)*
Share of noncollective without incentives to managers[a]		955		1,557
		(0.53)		(0.45)
Participation				
Participate in any activity of water management (1 = yes, 0 = no)		1,169		13,429
		(0.44)		(0.55)
Transparency				
Transparency in degree of water management		−2,419		−10,081
		(0.95)		(0.63)
Production environment				
Share of village irrigated area serviced by surface water	2,391	2,029	2,560	2,520
	(0.99)	(0.84)	(1.08)	(1.07)
Village water scarcity indicator variable (1 = yes, 0 = no)	−3,574	−3,703	−3,463	−3,549
	(3.13)***	(3.15)***	(3.03)***	(3.13)***
Value per hectare of accumulated investment into village irrigation infrastructure	−0.107	−0.038	−0.114	0.103
	(1.01)	(0.36)	(1.11)	(0.61)
Cropping structure				
Share of sown area in rice in 1995	10,592	10,590	10,655	10,740
	(4.18)***	(4.20)***	(4.23)***	(4.21)***
Household characteristics				
Age of household head	519	419	552	528
	(1.17)	(0.94)	(1.25)	(1.20)
Age of household head, squared	−6.282	−5.217	−6.705	−6.328
	(1.28)	(1.06)	(1.37)	(1.29)
Education of household head	−82	−66.9	−79	−46.8
	(0.50)	(0.41)	(0.48)	(0.28)
Farm size	−10,487	−8,629	−8,964	−6,338
	(2.23)**	(1.73)*	(1.89)*	(1.25)
Irrigation district indicator variables				
QID-N (Qingtongxia)	−9,888	−8,987	−9,968	−8,943
	(6.50)***	(5.95)***	(6.69)***	(4.55)***
PID-H (People’s victory)	−11,151	−10,743	−11,588	−10,584
	(4.94)***	(4.87)***	(5.12)***	(4.12)***
LID-H (Liuyuankou)	−15,752	−15,334	−16,105	−15,193
	(5.68)***	(5.64)***	(5.82)***	(5.05)***
Constant	14,261	15,725	13,822	12,172
	(1.43)	(1.57)	(1.39)	(1.22)
Observations	189	189	189	189
Adjusted R^2	0.44	0.45	0.45	0.45

[a]Noncollective institutions include WUAs and contracting.
Absolute value of t statistics in parentheses.
*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Source: Our calculations with survey data.

explanatory variables in our initial equations, an assumption that we subsequently relax.

Our empirical estimation, based initially on an ordinary least squares (OLS) estimator, performs well for our water use model (Table 4). The adjusted R^2 of around 0.45 is sufficiently high for analyses that use cross-sectional household data. Many coefficients on our control variables have the expected signs and are statistically significant. For example, we find that after holding other factors constant, households that are in villages with more rice area use more water per hectare than other crops. We also find that those villages that face more severe water shortages use less water per hectare.

After holding the other factors constant, our results show that nominally shifting management from the collective either to a WUA system or to contracting by itself does not lead to water savings (Table 4, column 1). The signs on the coefficients of the WUA and contracting variables are negative, suggesting that water use tends to be lower in villages that have moved to noncollective management (rows 1 and 2). However, the standard errors are all large relative to the magnitude of the coefficients, which implies that nominal institutional reform has no significant impact on saving water.

When officials provide water managers with incentives, without regard to whether they have shifted to WUA or contracting management, managers reduced water deliveries in the village (Table 4, column 2). The econometric results show that the coefficient on the incentive indicator variable is negative and significant (at the 10% level) when compared with the collective management, the omitted institutional type (row 3). In other words, without regard to the type of the water management institution, if managers face positive incentives, water use per hectare can be reduced by nearly 2,700 cubic meters, about 20% of their typical water use.

In contrast, our results show that the participation of farmers in water management does not reduce water use, as the corresponding coefficient is not significant in the water use equation (Table 4, row 5). These results imply that even when farmers are invited to participate in water management activities and the decision-making process, water use does not fall. While perhaps surprising, it should be remembered that although we randomly selected our villages, the sample only covers villages in old IDs that have been established for many years. It could be that in new irrigation systems, such as those in countries that the World Bank has supported, the role of participation could be more important (Reidinger, 2002). Also, it could be that in our sample villages, participation is not being encouraged in a way that is conducive to improving performance. In other words, if more active participation were encouraged, perhaps water management could be improved to the point that water could be saved.

Although the results based on OLS are interesting, it is possible that the estimated parameters are biased because water use per hectare and water management may be determined simultaneously, or the estimated coefficients may be affected by unobserved heterogeneity (or both). For example, it is possible that in areas that are facing rising demand for water from cities, farmers naturally reduce water use in anticipation of future water restrictions. At the same time, village leaders in the areas also may be trying to forestall shortages by adopting new institutional arrangements to show that they are concerned about the pending water crisis. In such a situation, the coefficient on the water management institution (or incentive) variable could be negative, even if the institution itself has no effect.

In order to control for the potential endogeneity of water management types, incentives and participation in the water-use equation, we adopt an instrumental variable (IV) approach. To do so, prior to estimating Eqs. (1) and (2), we regress a set of variables on the type of water management institution, $M_{k,}$, incentives for managers, I_k, and participation of farmers, F_k

$$M_k = \alpha + \beta IV_k + \gamma Z_k + \varepsilon_k, \tag{3}$$

$$I_k = \alpha + \beta IV_k + \gamma Z_k + \varepsilon_k, \tag{4}$$

$$F_k = \alpha + \beta IV_k + \gamma Z_k + \varepsilon_k, \tag{5}$$

where the predicted value of M_k from Eq. (3), $\hat{M}_k$, replace M_k in Eq. (1); and the predicted values of I_k and F_k from Eqs. (4) and (5), $\hat{I}_k$ and $\hat{F}_k$, replace I_k and F_k in Eq. (2). Equations (3)–(5) include $Z_{k,}$ which are measures of the other village-level control variables. The control variables in Eqs. (3)–(5) are the same as those in Eq. 1—for example, measures of the village's production environment and cropping structure.

In gauging the effectiveness of our IV approach, however, we need to be sure that the variables in the IV matrix in Eqs. (3)–(5) meet the definition of instruments. The key IV that we use in Eqs. (3)–(5) to address the endogeneity problem is a variable (P_k) that measures the effect of the decision of regional policymakers to push water management reform in village *k*. Such a measure should function well as an instrument, especially in our setting, because the officials who were responsible for promoting water management reform believed that at least in the short run they were choosing villages on a fairly random basis. An official in one ID told us that initially he went to villages in which he personally knew the local officials. If a typical water system official's acquaintances are independent of the amount of water used in the village, P_k should meet the criteria of an instrumental variable: it is correlated with the decision of a village to participate in water management reform but does not have an effect on water use (or income or crop production) except through the influence of the reform. We also include the age and education of the village leader as IVs.[15]

Examining the results of Eqs. (3)–(5) by themselves, the models perform well (complete results not shown due to space limitations). The adjusted R^2 statistics range from 0.21 to 0.94. Importantly, the results show that the water policy intervention variable, P_k, is positive and statistically significant. The variable meets the first criteria of an IV. Although the coefficient on the variables measuring village leader characteristics are insignificant, the Hausman test of the exclusion restrictions that

[15] We include village leader characteristics as IVs, following Li (1999). In his paper, Li claims that village leader characteristics may affect reform in the village, but that these characteristics would not have an independent effect on production decisions (in our case, water use).

Table 5
Incentives, production, income, and poverty in the sample irrigation districts (IDs), Ningxia and Henan Provinces, 2001

	Income (Yuan)	Cropping income (Yuan)	Poverty incidence (%)
Incentives to managers			
Noncollective with incentives[a]	2,334	1,073	11.1
Noncollective without incentives[a]	1,966	784	6.5
Collective	1,646	726	7.5
Participation of farmers			
With participation	2,267	931	0
Without participation	1,829	799	8.4

[a]Noncollective institutions include both WUAs and contracting.
Source: Authors' survey.

are designed to test the validity of the set of instrumental variables show that our choice of instruments are statistically valid and meet the second criterion of IV.[16]

When the predicted value of the water management variable is put into the water use model in Eq. (1), results (Table 4, columns 3 and 4) change little and largely support the findings from the OLS model. Compared with the OLS estimates, the *t*-ratio of the estimated coefficient on the incentive variable increases (row 3). The magnitude of the coefficient also suggests that the savings from providing incentives are large. Holding other variables constant, in the villages in which leaders offer managers positive incentives, water use declines more than 6,000 cubic meter per hectare, about 40% of average water use (row 3, column 4). Participation, however, still has no significant impact on water use.

5. Incentives to managers, participation of farmers, income and poverty

Water management reform, at least when implemented as designed, leads to water savings and meets the primary goal of water sector officials. However, the success of such a policy might come at a cost, either in terms of falling income or increased poverty. In this section, we examine how water management reform, especially as measured by the nature of incentives faced by managers and the participation of farmers, affects farmer income and the incidence of poverty.

Descriptive statistics do not show any evidence of a negative impact of incentives on farmer income (Table 5). Evidence from our survey reveals that in the villages in which leaders reformed their water management systems and provided incentives to managers, farmers actually earn higher income (row 1, column 1). Surprisingly, crop income is also higher in villages that have provided managers with incentives (column 2). Part of the explanation for the differences in income may be partly due to the fact that water fees are also changed in villages that have reformed. It also may be that farmers are shifting their production decisions and allocating labor to other enterprises in villages that provide water managers with incentives. As in the case of water-use analysis, however, the complexity of the problem suggests that econometric analysis is needed to isolate the effect of reform on income. Econometric analysis also appears to be needed to distinguish between income and poverty effects; in contrast to the case of income, our descriptive data show that poverty actually is worse in those villages that provide managers with incentives (column 3). Farmer participation does not appear to have negative influence on farmer income or poverty (rows 4 and 5).

5.1. Multivariate empirical model and results

In addition to water management reform, other socioeconomic factors also influence income and poverty. In order to study whether water management reform affects these outcomes, it is necessary to control for these other factors. To do so, we establish the following equation to examine the relationship between income and other factors:

$$y_{jk} = \alpha + \beta I_{jk} + \gamma F_{jk} + \delta Z_{jk} + D_{jk} + \varepsilon_{jk}, \qquad (6)$$

where y_{jk} represents either total or cropping income per capita for household j, and the other variables are as defined above. In examining the effect of water management reform on poverty, we proceed in largely the same way. Because we are measuring poverty in terms of income, we use largely the same specification and expect similar results, but with opposite signs.

Almost all the models analyzing the effect of water management reform on income and poverty perform well and produce robust results that largely confirm our *a priori* expectations (Tables 6 and 7). The goodness-of-fit measures for income models range from 0.24 to 0.35. Many coefficients on our control variables are of expected sign and statistically significant. For example, the production shock variable shows that droughts and floods not only reduce farmer income, but also adversely affect the household's poverty status. Farm size has a positive effect on incomes.

Our research results also demonstrate that water management reform has no statistically significant impact on farmer income (Table 6). When we use either an OLS or IV approach, the coefficients on the incentive and participation of farmers variables in the total and cropping income models are all statistically insignificant (rows 1 and 3). These results are consistent with our descriptive statistics. In fact, the results of our production models (not shown here) indicate that after reform, due to the reduction of water use, wheat yields will decline about 10% while maize and rice yields remain constant (Wang et al., 2003).

[16] To test if the set of identifying instruments is exogenous, a Lagrange multiplier test can be used (Hausman). The chi-square-distributed test statistic with three degree of freedom, is $N * R^2$, where N is the number of observations, and R^2 is taken from the regression of the residuals from the water use Eq. (1) on the variables that are exogenous to the system. The test statistics are 1.56 for Eq. (1) and 1.44 for Eq. (2). The test results indicate the null hypothesis that there is no correlation between the exogenous instruments and the disturbance term from water use Eq. (1) cannot be rejected.

Table 6
Regression analysis of determinants of farmer income

	Total income per capita		Cropping income per capita	
	OLS	IV	OLS	IV
Water management institutions				
Incentives				
Share of noncollective with incentives to managers[a]	203	838	−118	91.5
	(0.61)	(1.24)	(0.90)	(0.35)
Share of noncollective without incentives to managers[a]	−15.7	−383	38.5	−44.5
	(0.05)	(0.57)	(0.28)	(0.17)
Participation				
Participate in any activity of water management (1 = yes, 0 = no)	232	2,496	27.7	1,700
	(0.45)	(0.53)	(0.14)	(0.92)
Transparency				
Transparency in degree of water management	−161	−1,344	−256	−1,263
	(0.33)	(0.44)	(1.34)	(1.06)
Production environment				
Share of village irrigated area serviced by surface water	345	311	−132	−123
	(0.74)	(0.68)	(0.72)	(0.68)
Village water scarcity indicator variable (1 = yes, 0 = no)	182	142	−12.3	−6.238
	(0.79)	(0.64)	(0.14)	(0.07)
Value per hectare of accumulated investment in village irrigation infrastructure	0.069	0.060	0.014	0.016
	(3.35)***	(1.83)*	(1.76)*	(1.22)
Cropping structure				
Share of village rice area in 1995	215	232	−43.1	−21.9
	(0.44)	(0.47)	(0.23)	(0.11)
Household characteristics				
Age of household head	179	176	49.5	52.6
	(2.05)**	(2.04)**	(1.46)	(1.55)
Age of household head, squared	−1.701	−1.689	−0.575	−0.606
	(1.76)*	(1.76)*	(1.53)	(1.61)
Education of household head	23.0	21.7	−6.673	−6.671
	(0.73)	(0.68)	(0.54)	(0.54)
Farm size	3,205	2,990	3,267	3,149
	(2.86)***	(2.65)***	(7.36)***	(7.00)***
Total productive asset per capita	0.112	0.110		
	(3.48)***	(3.45)***		
Assets used in agricultural production per capita			0.077	0.080
			(1.66)*	(1.72)*
Number of plots per household	−125	−129	−4.577	−6.509
	(3.68)***	(3.80)***	(0.35)	(0.49)
Production shocks				
Production shocks	−233	−220	−189	−182
	(1.24)	(1.18)	(2.59)**	(2.49)**
Irrigation districts indicator variables				
QID-N (Qingtongxia)	−302	−457	−145	−234
	(1.01)	(1.17)	(1.23)	(1.50)
PID-H (People's victory)	−1,065	−1,177	−69.9	−115
	(2.38)**	(2.25)**	(0.40)	(0.56)
LID-H (Liuyuankou)	−938	−1,059	−63.1	−108
	(1.75)*	(1.77)*	(0.30)	(0.46)
Constant	−2,599	−2,332	−465	−492
	(1.34)	(1.21)	(0.62)	(0.65)
Observations	189	189	189	189
Adjusted R^2	0.24	0.24	0.35	0.35

[a]Noncollective institutions include both WUAs and contracting.
[b]Productive assets include assets used for agricultural and nonagricultural production activities.
Absolute value of *t*-statistics in parentheses.
*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Source: Authors' calculations with survey data.

Table 7
Regression analysis of determinants of poverty

	Dummy of poverty[b]	
	OLS	IV
Water management institutions		
Incentives to managers		
Share of noncollective with incentives to managers[a]	0.069	0.063
	(0.96)	(0.43)
Share of noncollective without incentives to managers[a]	0.033	−0.072
	(0.45)	(0.49)
Participation		
Participate in any activity of water management (1 = yes, 0 = no)	−0.146	−0.166
	(1.33)	(0.16)
Transparency		
Transparency in degree of water management	0.095	0.163
	(0.89)	(0.24)
Production environment		
Share of village irrigated area serviced by surface water	−0.180	−0.167
	(1.79)*	(1.67)*
Village water scarcity indicator variable (1 = yes, 0 = no)	−0.014	−0.007
	(0.29)	(0.15)
Value per hectare of accumulated investment in village irrigation infrastructure	−0.000	−0.000
	(1.16)	(0.92)
Cropping structure		
Share of village rice area in 1995	0.002	0.013
	(0.02)	(0.12)
Household characteristics		
Age of household head	0.010	0.008
	(0.56)	(0.43)
Age of household head, squared	−0.000	−0.000
	(0.70)	(0.59)
Education of household head	−0.010	−0.010
	(1.47)	(1.41)
Arable land per hectare of household	−0.242	−0.260
	(1.00)	(1.06)
Total productive asset per capita	−0.000	−0.000
	(0.79)	(0.72)
Number of plots per household	0.013	0.013
	(1.78)*	(1.78)*
Production shocks		
Dummy of production shocks (1 = yes, 0 = no)	0.097	0.095
	(2.40)**	(2.32)**
Irrigation district indicator variables		
QID-N (Qingtongxia)	0.027	−0.001
	(0.42)	(0.01)
PID-H (People's victory)	0.044	0.006
	(0.46)	(0.05)
LID-H (Liuyuankou)	−0.048	−0.084
	(0.41)	(0.64)
Constant	0.014	0.103
	(0.03)	(0.25)
Observations	189	189
Adjusted R^2	0.01	0.001

[a]Noncollective institutions include WUA and contracting.
[b]If per capita net income of household is lower than the national poverty line (625 Yuan per capita per year in 2001), the dummy of poverty is 1; otherwise, the dummy of poverty is 0.
Absolute value of *t*-statistics in parentheses.
*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Source: Authors' calculations with survey data.

Our results suggest that whatever negative income effect there is from falling wheat production, it is being offset partially by reductions in water fees.[17] Similar to the results for incentives, farmers will not earn less money due to their participation in water management.[18] Because participation of farmers has no effect on water use, it is not hard to understand why it has no negative influence on farmer income.

Similar results can also be found in the poverty model. Because we measure poverty status as "under the poverty line or not," our results indicate that there is no effect on household poverty status even when villages decide to provide water managers with incentives or involve farmers in water management. If universally true, such a finding would be important, especially for the case of offering managers with greater incentives. Critics of water management reform often point out that one possible adverse consequence of using incentives to induce water savings is that managers may cut back on water deliveries to marginal users, who may also be those on the poorest land with the lowest incomes.

Our results here, however, should be interpreted with caution. First, we have not identified what may be behind this result. In many villages, leaders have specified strict rules in their agreements with water managers that they cannot exclude households from water allocation schedules. Second, as seen by examining the estimated equations in Table 7, only a few of the coefficients are significant, a sign that our sample may be too small to identify poverty effects. In short, while interesting, we believe our current results may be more important as a tool that raises awareness of possible associations rather than providing definitive answers. Future research should try to pinpoint the source of this effect and use larger data sets to strengthen our understanding of these issues.

6. Conclusion

In this article, we have sought to understand the reform of China's surface water management systems and its effect on water use, income, and poverty. Research results show that since 1990, collective water management has been replaced by WUAs and contracting. In some regions reform institutions have become the dominant form of management. Spread mostly by the efforts of water officials, we have shown that implementation has often deviated from theory. Participation by farmers has played only a minor role in most villages. In some villages reform has been only nominally implemented, and there are

[17] For most of the farmers in our study sites, the water fee is less than 10% of the gross value of output.

[18] In some areas of China, observers have noted arrangements in which village governments agree to pay for a targeted amount of water that is supplied to the village by the ID, but can make adjustments to the amount of fees that are ultimately charged to the farmers based on the actual amount of water provided. In other words, savings are passed on to farmers and are not captured by the canal managers. While this is interesting, this is not what is happening in our study villages.

few apparent differences when comparing the "reform" institutions to traditional management forms. In part because of these implementation problems, our analysis has shown that nominal reform has had little effect on water use.

The absence of a systematic relationship between nominal reform and water use, however, does not mean that the entire reform process has failed. 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 water savings while having only a small or no effect on agricultural production, rural incomes, and poverty. 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 because the output of major crops, such as rice and maize, did not fall, and rural incomes and poverty remained statistically unchanged. Only wheat production fell (Wang et al., 2003). Although our study needs to be undertaken in other areas in the future before the results can be generalized to the rest of China, at least in the sample sites that provided their manager incentives, water management reform has been nearly a win-win policy.

Overall, we believe that our findings support the conclusion that the government should continue to support water management reform. Officials who want the reforms to succeed should make an effort to ensure that more emphasis is put on effective implementation. Although no negative impacts on production and farmer income were found, in the longer run, as water management reform reaches into more water scarce areas and seeks to continue to achieve water savings in areas that have already cut back on use, there may be sharper tradeoffs between water use and production and income. When the tradeoffs are larger, officials still may choose to opt for pushing reforms that save water. In these cases, because the farmers who lose access to water could also suffer production and income reductions, policies to mitigate the adverse consequences should be developed.

Although the literature emphasizes the importance of participation for water management reform, we find little, if any, effect of participation by farmers on water use in our sample sites. Perhaps the degree of participation in our sample sites is so low that it does not play an important role. Our survey shows that, in fact, farmers have not participated actively in many important activities of water management. In any event, the results suggest that further analysis of the determinants and effect of participation is needed.

Acknowledgments

The authors would like to thank David Dawe, Richard E. Howitt, Qiuqiong Huang, Bryan Lohmar, Siwa Msangi, and Jame Wilen for their insights and helpful suggestions. We also thank two anonymous referees and Von Cramon for helpful comments. A special thanks is given to Intizar Hussain and Eric Biltonen, our colleagues from the International Water Management Institute (IWMI) who led the project under which our research was conducted. We acknowledge financial support from the National Natural Sciences Foundation (70021001) in China, IWMI, the Asian Development Bank, and Australian Center of International Agricultural Research (ADP/2000/120). We also acknowledge the USDA's NRI research grants program for supplemental support of this project. Scott Rozelle is a member of the Giannini Foundation.

Appendix: Calculation of crop water use

Because measuring water use in villages that use surface water is always a difficult task, during the enumeration process we developed a methodology that was based on a strategy of eliciting information from more than one respondent in each community and asking about water use in a number of ways. To implement this strategy, we included special blocks on water use in both the village and canal manager forms. We also asked ID officials in each area for the information that could be used to check our survey-based estimates. We not only asked the respondents to provide estimates of water use per hectare in the sown area that was actually irrigated, we also recorded other information about the application process, such as the length of time that it took to apply water in the village, the depth to which the average field was flooded, the types of the soil, and the area irrigated. We elicited these data for each irrigation for each crop during the season.

The data that we collected in the different survey forms were used to create a household-level (and plot-level) measure of average water use per hectare for each crop for each village. The first step involved comparing the direct estimates of water use per hectare from village leaders and canal managers by crop and by irrigation. If both of these respondents provided estimates, and neither of the estimates exceeded or fell below the feasibility range that was estimated by the local ID officials, we averaged the two estimates. According to our survey, nearly 80% of village leaders and canal managers were able to provide relatively accurate estimates of this number. If one or both of the respondents were unable to provide a direct estimate of water use, we then used the other information about the village's irrigation system (e.g., length of time that it took to apply water in the village, the depth to which the average field was flooded, the type of the soil and area irrigated) to predict water use. We used these predictions in the same way as the raw data and compared them with the estimates of the other respondent and boundaries set by the local ID officials. At this point of the analysis, each village had a set of parameters that measured the average amount of water used per hectare per irrigation for each crop. Combining these parameters with plot level data (which provided information on the number of irrigations used on each crop by each household), we were able to aggregate across crops (weighted by their area shares) and produce a household-level measure of water use per hectare.

Table A.1
Descriptive statistics for major variables

	Mean	Standard deviation	Minimum	Maximum
Share of WUA management	0.14	0.34	0	1
Share of contracting	0.22	0.39	0	1
Share of noncollective with incentives to managers	0.16	0.36	0	1
Share of noncollective without incentives to managers	0.20	0.39	0	1
Dummy of governmental intervention for WUAs	0.14	0.35	0	1
Dummy of governmental intervention for contracting	0.30	0.46	0	1
Dummy of participation in any activity of WUA management by farmers	0.06	0.24	0	1
Dummy of participation in the decision to establish a WUA management by farmers	0.02	0.14	0	1
Dummy of participation in the selection of WUA managers by farmers	0.04	0.20	0	1
Dummy of participation in the regular meeting of WUA managers by farmers	0.04	0.20	0	1
Age of village leader (years)	43	7	29	55
Education of village leader (years)	9	3	0	15
Share of village water scarcity indicator variables	0.73	0.41	0	1
Village water scarcity indicator variables	0.27	0.45	0	1
Value per capita of accumulated investment in village irrigation infrastructure (Yuan)	2,824	4,881	0	33,943
Share of village rice area in 1995 (%)	0.19	0.21	0	0.80
Household crop water use per hectare (m^3)	15,365	8,739	627	44,580
Water use per hectare wheat (m^3)	5.937	3,909	300	21,000
Water use per hectare maize (m^3)	6.936	4.802	360	27.750
Water use per hectare rice (m^3)	28,882	18,572	1,381	89,072
Household total income (Yuan)	1.855	1.426	−42	11.087
Household cropping income (Yuan)	806	604	−135	4,285
Dummy of poverty	0.08	0.27	0	1
Age of household head (year)	44	9	24	66
Education of household head (year)	6	3	0	15
Farm size (hectares)	0.17	0.12	0.03	1.03
Total productive assets per capita (Yuan)	1,434	2,972	2	32,533
Assets used in agricultural production per capita (Yuan)	906	857	1	4,800
Number of plots per household (number)	7	4	1	23
Dummy of production shocks	0.52	0.50	2	1
Wheat yield per hectare (kg)	4,740	1,253	375	8,625
Maize yield per hectare (kg)	5,760	1,770	600	10,125
Rice yield per hectare (kg)	6,900	1,740	1,125	12,855

Source: Authors' survey.

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