Water Management Reforms in the Yellow River Basin: Implications for Water Savings, Farm Incomes and Poverty

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Abstract

The overall goal of our paper is to better understand water management reform in China's communities, especially focusing on the effect that it will have on the nation's water resources and the welfare of the rural population. To pursue this goal, the paper has three objectives. First, we track the evolution of water management reform and seek to identify the incentives mechanisms that encourage water managers to more efficiently use water. Second, we identify the impact of water management reform on crop water use, the primary motivation of the policy. Finally, the paper explores how changes in China's water management reform affect agricultural production, farmer income and poverty. Based on a random sample of 51 villages, 189 farmers and 378 plots in four large irrigation districts in Ningxia and Henan provinces, both provinces in China's Yellow River Basin, our results show that two of the main forms of water management reform, Water User Associations and contracting, have begun to systematically replace traditional form of collective management. The impacts analysis demonstrates that it is not the nominal implementation the reform that matters, but rather it is the creation of new management institutions that offer managers incentives to save water. Specifically, when managers in reformed organizations are provided with incentives, they save water. Importantly, given China's concerns about national food production and poverty allevation, the reductions in water do not lead to reductions in either production, income or higher incidences of poverty.

Key words: Water Management Reform, Water User Associations, Contracting, Incentives

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Introduction

The Chinese government has identified increasing water scarcity as one of the key problems that must be solved if the nation is to meet the objectives of its national development plan in the coming years (Zhang, 2001). Shortages of water are harming efforts to alleviate poverty as well as becoming a major source of environmental problems (World Bank, 1998; Zhang, 2000). In many regions of the country, rapidly growing industry and an expanding and increasingly wealthy urban population regularly out compete the nation's farmers for limited water resources, threatening to curtail growth in food production.

In facing the emerging water crisis, leaders typically debate about which of several approaches should be used to address water scarcity problems, although no option has proved very successful (Lohmar et al., 2002). Developing more water resources to increase water supply historically has been given the highest priority in resolving water shortages. Since the 1950s, China's government has invested more than 127 billion US dollars for the construction of infrastructure to develop new water resources (Wang, 2000). Recently, the State Council announced plans to allocate more than 50 billion US dollars for the construction of a project to move water from the Yangtse River Valley to northern China. Despite such ambitious goals, the high cost of developing new sources of water will make it so that the volume of water that can be added to north China's water equation will only be marginal. Leaders also have promoted water saving technologies and considered whether or not they should use water pricing policy (Chen, 2002; Rosegrant and Cai, 2002). Unfortunately, most efforts to encourage the use of sophisticated water saving technologies, such as drip and sprinkler irrigation, have failed and in the past several years the Ministry of Water Resources has distanced itself from a water policy based on water-saving technology (Zai, 2002). Moreover, political considerations will most likely keep leaders from moving too aggressively to raise prices, at least in the agricultural sector (Rosegrant and Cai, 2002).

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

Despite consensus of the current leadership in China to push water management reform, there is considerable debate about its appropriateness. International evidence shows that water management and its institutional arrangements are important measures for dealing with water shortage problems (World Bank, 1993; IWMI and FAO, 1995). Since the 1980s, many developing countries have begun to transfer irrigation management responsibilities from the government to farmer organizations or other private entities in order to mitigate the financial burden of water projects and to improve the efficiency of water use and supply (Vermillion, 1997). Decentralized water resource management, if structured properly, can provide the incentives needed to stabilize and improve the efficiency of irrigation and water supply system. There are some cases internationally where these efforts have failed or even generated negative influences (Easter and Hearne, 1993; Vermillion, 1997; Groenfeldt and Svendsen, 2000).

In fact, since the early 1980sand increasingly in the late 1990s, China's policy makers have promoted water management reform, and like similar attempts outside China, the record seems to be mixed although most evaluations are based only on anecdotes or case studies (Nian, 2001; Huang, 2001; China Irrigation Association, 2002). Even in those areas in which management reform has been well-designed, effective implementation of the reform has been difficult (Ma, 2001; Management Authority of Shaoshan Irrigation District, 2002). Collective action, information problems, and getting the incentives right are among the most important reasons that water management reform has failed. The design of water management reforms themselves also may create a number of negative externalities. Since the reforms provide financial incentives to the manager to more efficiently manage water, it is possible that the manager could take a number of actions that could negatively affect production, income and the poverty status of certain individuals. For example, managers could deliver less water than demanded by farmers or cut off water deliveries to slow-paying, poor households. Surprisingly, despite the high stakes of the reforms there is little or no empirically based work that has been conducted to understand and judge the effectiveness of water management reform.

The overall goal of this paper is to better understand water management reform in rural communities in China's Yellow River Basins, especially focusing on the effect that it will have on the nation's water resources in farming. To pursue this goal, the paper has three objectives. First, we track the evolution of water management reform and seek to identify the incentives mechanisms that encourage water managers to more efficiently use water. Second, we identify the impact of water management reform on crop water use, the primary motivation of the policy. Finally, the paper explores how changes in China's water management institutions also affect agricultural production, farmer income and poverty.

Study Settings and Data

The data for our study come from a survey conducted in 51 villages in four irrigation districts (IDs) in Ningxia and Henan provinces. To increase the variation among regions, provinces were chosen that were located in the upper (Ningxia) and lower reaches (Henan) of the Yellow River Basin (YRB). In selecting the irrigation districts for our study, a number of criteria were considered. From a number of IDs in each province, the two IDs were chosen based primarily on water availability, doing so 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 the census of villages in the upper, middle and lower reaches of the canals within the IDs.[1] Enumerators also randomly chose four households within each village. After getting the basic information about each plot, the enumerators chose two plots from each household for more careful investigation. In total, we surveyed 51 villages leaders, 56 water managers, 189 farm households and gathered information on 378 farm plots.

In order to meet the study's objectives, we designed three separate survey instruments: one for farmers, one for canal managers and one for village leaders. During our survey, three types of management institutions were identified: collective management, Water User Associations (WUAs) and contracting. In our village and canal management questionnaires we recorded the share of canals within the village that is controlled by each management type for each of three years (1990, 1995 and 2001). In addition, enumerators also asked about how managers were compensated. When managers have rights to the earnings of the water management activities (that is, to the value of the water saved by water management reform), we say that they face strong incentives (or henceforth, refered to as "*with incentives*"). If the incomes from their water management

[1] The two IDs in Ningxia Province are Weining Irrigation District and Qingtongxia Irrigation District. The IDs in Henan Province are People's Victory Irrigation District Liuyuankou Irrigation District.

duties are not connected to water savings, they are said to be "*without incentives*".

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

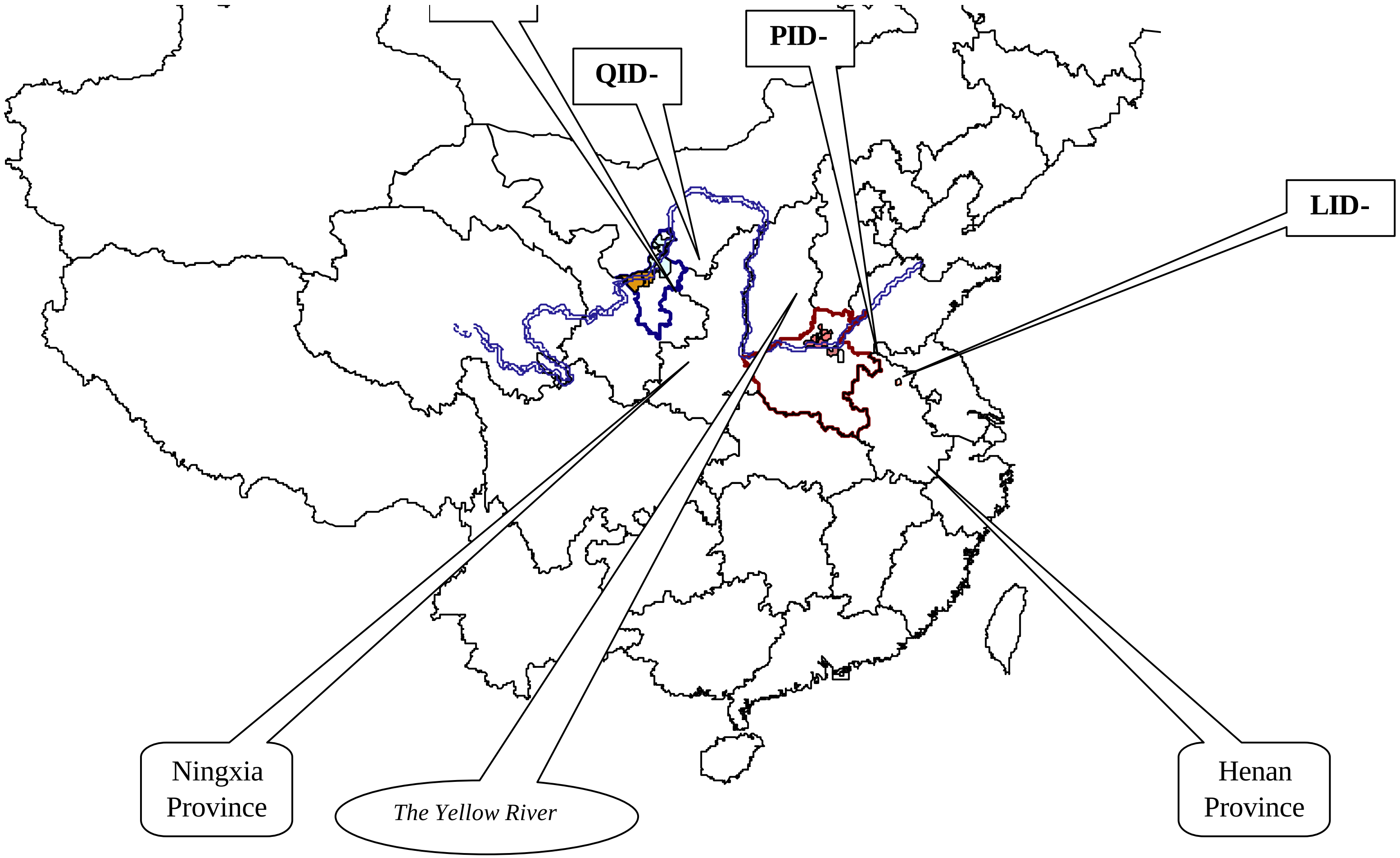

Figure 1 Location of the selected irrigation districts

We also systematically collected information on both income and crop production by plot and by crop for all cropping seasons during the year 2001. Income is an estimate of each household's full net income and includes all major sources of income of the household, including that from cropping, livestock, off farm wage labor, earnings from the family's business enterprise, and other miscellaneous sources. With information on income, we were able to construct a measure of poverty status by comparing household per capita income (dividing total household income by the number of family members, which include the household head, the household head's spouse and all individuals that lived in the household for at least three months per year) with the national poverty line (625 yuan per capita per year in 2001).

The rest of the survey instrument asked for information about several other important variables believed to affect either water management institutions, outcomes or both. For example, village leaders and water managers were asked if upper-level government officials took steps to encourage the extension of 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, as well as a number of other village, household and plot characteristics. Descriptive statistics of the main variables are shown in Appendix B.

Evolution of Water Management Reforms

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

According to our data, since the early 1990s and especially after 1995, reform has successively established WUAs and contracting in the place of collective management (Table 1). The share of collective management declined from 91 percent in 1990 to the 64 percent in 2001 (column 5). Across our sample, contracting has developed more rapidly than WUAs. By 2001, 22 percent of villages managed their water under contracting and 14 percent through WUAs. Assuming the results from our sample reflect the more general trends across north China, the somewhat more rapid emergence of contracting may be due to the ease of setting the system up and the similarities of the reforms to the other reforms that have unfolded in rural China (Nyberg and Rozelle, 1999).[2]

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 in Henan (Table 1). For example, in 1995, the collective ran 100 percent of the water management institutions in one of the Ningxia IDs (column 1). By 2001, however, the collective managed water in only 27 percent of the sample villages. WUAs managed water about 23 percent of the villages and contracting managed water in approximately 50 percent. In Ningxia's other sample ID, the share of villages under WUAs and contracting approached 49 percent, almost the same as those under collective management (column 2). In contrast, significantly less reform occurred in Henan. Only eight percent of the villages in one of the sample IDs and none in the other have moved to either contracting or WUAs (columns 3 and 4).

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

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

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 (or at least relaxing constraints to) reform.

The differences among the villages in Ningxia and variations in the way that different regions implemented the reforms (i.e., some moved to contracting while others shifted to WUAs) show that the reforms are far from universal. In fact, this is what would be expected in China, a nation that often allows local governments considerable room in making their own decisions on the exact form and timing of institutional changes (Jin, Qian and Weingast, 2000). In contrast, neither the Henan provincial government nor any of the prefectural governments have issued directives mandating reforms.

Variation in governance of various water management forms

While the shift in China's water management institutions demonstrate that the nation's communities are following policy directives that are being developed and issued from upper-level governments, when local leaders set up their organizational frameworks in their villages, practice often varies from theory. For example, in practice, at least in the early stages of the development of WUAs (the only stage of the organizations that we are observing since this type of management is so new), the organization of most WUAs varies sharply from theory. In most cases (70 percent of the WUAs), the governing board of the WUA was the village leadership itself. In a minority share of the cases (30 percent of the WUAs), village leaders appointed a chair or manager to carry out the day-to-day duties of the WUAs. In many of these WUAs that had village-appointed leaders, however, the manager actually had close ties to the village leadership, more than half being a leader in an earlier time period. In other words, in terms of the composition of the management team, most WUAs differ little from collective management.

An examination of the way the managers are compensated perhaps shows the greatest difference between theory and practice. To show this one needs to understand the way farmers pay fees, managers are compensated and how IDs are paid. In fact, water management reform has created a complicated system of fees, payments and charges that embody the primary incentives for the managers to save water. Water fees collected from farmers include two parts: *basic water fees* associated with the fixed quantity of land in the village and *volumetric water fees* associated with the volume of water use. Set by water bureau officials, the farmer is required to pay the basic water fee (which is based on his land holdings) and part of the basic water fee belongs to the water manager after it is collected. This part of the manager's compensation is paid to him as a *fixed payment* and provides little or no direct incentives to save water.[3]

Higher level officials, however, can use the other part of the water fee to provide managers with more direct incentives. Prior to the farming year, ID officials determine (on the basis of historic use patterns and other criteria) a targeted amount of water that a village should use (called the *target quantity*). Based on a per cubic meter charge, the total value of the expected water use for the village is then divided by the village's total quantity of land and this volumetric water fee is added to the basic water fee to create the farmer's total water fee. Therefore, this form of a volumetric water fee provides the farmer with no incentives to save water since he pays a fixed fee for each hectare of land. The water manager in some communities, in contrast, does have an incentive. 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 (*actual quantity*). If the actual quantity of water delivered to the village (at the request of the water manager) is less than the targeted quantity, the difference between the volumetric fee that is collected from the farmers and that which he pays for the water is his *excess profit*. The excess profit is an amount that is earned by the manager beyond the fixed payment.

According to the data, there are sharp differences in the way that villages have implemented the incentives part of the reform packages, regardless of whether they are WUAs or contracting (Table 2). For example, in 2001, on average, leaders in only 41 percent of villages offered WUA and

[3] Once the manager collects that total fee from the farmer, he turns the basic fee part to the village accountant who in turn sends it to the township which is supposed to use the funds to maintain the township's canal infrastructure.

contracting (or *non-collective*) managers with incentives that could be expected to induce managers to exert effort to save water in order to earn an excess profit (row 1). 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 incentives point of view, the WUA and contracting managers faced no incentives (row 1). In these villages, water managers are like village leaders in a collectively managed system in that they do not have a financial incentive to save water. The incentives offered the managers also differ across IDs (rows 2 to 6). Hence, to the extent that the incentives are the most important part of the reform, the differences acr oss time and space mean that it would not be surprising if in some villages WUAs and contracting were more effective at saving water than in other villages.

Water Management and Crop Water Use

Although the major objective of water management reform is to save water, descriptive statistics using survey data are unclear in that they show that water use in areas with established WUAs and contracting compared to those areas still under collective management is lower in some areas, but higher in other areas (Table 3). For example, in the second ID in Ningxia (ID2), the water use per hectare in areas that have reformed (WUAs and contracting) is lower than those areas in which the collective still manages the water (rows 5 and 6 versus row 4). However, in Ningxia's other ID (ID1) and in Henan, water use per hectare is higher in those villages that have shifted to WUAs or contracting (rows 1 to 3; 7 and 8).

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 thos e that do not (Table 4). After reform, when managers face incentives to earn profits by saving water, water use per hectare fall by nearly 10 percent when compared to collectively managed systems across our Ningxia sample (row 1, columns 1 and 3). In contrast, when leaders implement water management reform without providing incentives, water use rises (column 2). When examining the individual IDs in Ningxia, it was also found that in both cases water use either falls more or does not rise as much, as when incentives are provided during reform than when they are not. In ID2, for example, water use falls in both non-collective systems with and without incentives, but it falls further for those with incentives (row 3). In ID1, although water use in the both non-collective systems rises, it rises by less for those with incentives (row 2). We also find the same patterns occur when examining individual crops (rows 4 to 6).

While our descriptive analysis shows that there is a positive correlation between incentives and water savings, in fact, there can be many other factors that are correlated with incentives that are creating the tendency of incentives and water savings to move together. In particular, it can be that cropping structure, the nature of the canal system's investment and the scarcity of water may affect the managerial type, the way that reforms are implemented and water use. As a result, multivariate analysis is required to analyze the relationship between water management reform and water use and other outcomes.

Multivariate Empirical Model and Results: Water Management Institution and Incentives Impact on Water Use

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

$$w_{jk} = ?\ ?\ ?M_{k}\ ?\ ?Z_{jk}\ ?\ D_{jk}\ ?\ ?_{jk} \qquad (1)$$

where w_{jk} represents average water use per hectare for household j in village k. The rest of the variables explain water use: M_k, our variable of interest, measures either the type of the water management institution or the nature of the incentives faced by the water manager; Z_{jk}, a matrix of control variables, represents other village and household factors that affect water use.

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 such as the source of water (either surface or ground), the degree of water scarcity and the level of irrigation investment per hectare to measure the production environment. Cropping structure is measured as the proportion of the village's sown area that is in rice. Household characteristics include age and education of the household head and land endowment. Finally, our model also includes D_{jk}, a dummy variable representing the ID that serves the household. The symbols *a*, *ß*, and *?* are parameters to be estimated and e_{jk} is the error term that is assumed to be uncorrelated with the other explanatory variables in our initial equations , an assumption that is subsequently relaxed.

Our empirical estimation performs well for our water use model (Table 5). The goodness of fit measure, the adjusted R^2, 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 constant other factors, 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 constant other factors, our results show that the mere fact of shifting management from the collective to either a WUA system or contracting by itself does not lead to water savings (Table 5, column 1). In fact, the signs on the coefficients of the WUA and contracting variables are negative, suggesting that water use is 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 when officials provide water managers with incentives, without regard to whether they shifted to WUA or contract management, managers appear to reduce water deliveries in the village (Table 5, column 2). Econometric results show that the coefficient on the incentive indicator variable is negative and significant (although only at the 10 percent level), when compared to the collective management, the omitted institutional type (row 3). In other words, without regard to the form of the water management institution, if managers face positive incentives, water use per hectare can be reduced by nearly 3000 cubic meters, about 20 percent of their typical water use.

Although interesting, it is possible that the estimated parameter is biased since water use per hectare and water management may be determined simultaneously with water use or that the estimated coefficient is affected by unobserved heterogeneity. 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 the 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 and incentives in the water use equation, we adopt an instrumental variable (IV) approach. To do so, prior to estimating equation (1), a set of variables is regressed against the water management institution variable, M_k:

$$M_k = ? \; ? \; ?IV_k \; ? \; ?Z_k \; ? \; ?_k \qquad (2)$$

where the predicted value of M_k from equation (2), $\hat{M}_k$, would replace M_k in equation (1). Equation (2) includes Z_k, which are measures the other village-level control variables (which are the same as those in equation 1 (e.g., measures of the village's production environment and cropping structure).

This IV procedure, however, is only valid if the variables in the IV matrix in equation (2) meet the definition of instruments. The key IV in the equation (2) that we use to address the endogeneity problem is a variable (Pk) that measures the effect of the decision of regional policymakers to promote water management reform in village *k*. Such a measure should function well as an instrument, especially in our setting, since the officials that 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 the spectrum of the acquaintances of the typical water system officials are independent of the amount of water used in the village, our policy variable 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.[4]

Examining the results of equation (2) by itself, the model performs well (Appendix C). The adjusted R-squares range from 0.23 to 0.94. Importantly, the results show that 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 are designed to test the validity of the instruments show that our instruments are statistically valid and meet the second criteria of IVs.[5]

When putting the predicted value of the water management variable into the water use model in equation (1), our results change little and largely support the findings from the OLS model (Table 5, columns 3 and 4). Compared with OLS estimation, the t-statistic of the estimated coefficient on the incentive variable actually rises (row 3). The magnitude of the coefficient also suggests that the savings from providing incentives are large, and in fact even greater. Other variables held constant, where village leaders offer managers positive incentives, water use declines more than 6000 cubic meter per hectare, or about 40 percent of average water use (row3, column 4).

Water Management, Production, Income and Poverty

Water management reform, at least when implemented as designed, leads to water savings and meets the primary goal of the water sector officials. However, it is possible that the success from such a policy can only come at a cost, either in terms of falling production or income or increased poverty. In this section, we examine how water management reform affects agricultural production. We then examine its impact on income and the incidence of poverty.

Descriptive statistics from our data show that water management reform negatively influences agricultural production (Table 6, rows 1 to 3). Compared with collective management, in the villages that provide incentives to managers to save water, wheat yields decline by near 10 percent. Maize and rice yields also decline by 9 and 12 percent, respectively. The negative effect of incentives on production is even clearer when comparing the yields between villages that nominally implement reforms but do not provide incentives to water managers with those that do provide incentives (rows 1 to 3, column 1 versus 2). In the case of wheat and maize yields, while production in villages with managers that have positive incentives fall, those in villages that have moved to WUAs and contracting but have not provided incentives actually rise marginally. In the case of rice, yields fall for villages that only reform nominally fall, but not as far as for villages that provide incentives to their managers. Since the pattern in production is consistent with, though in the opposite direction, the correlations between water management and water use, suggest that water savings through management reform may only be able to come at a cost of lower yields.

In contrast, the negative influence of water management reform on production does not appear in the descriptive statistics when examining farmer income (Table 6). Evidence from our survey reveals in the villages in which leaders reformed their water management system and provided incentives to managers, farmers actually earn higher income (rows 4). Surprisingly, crop income is also higher in villages that have provided managers with incentives (row 5). Part of the

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[4] We include village leader characteristics as IVs, following Brandt et al. (2003) and Li (1998). In these papers, the authors claim that village leader characteristics may affect reform in the village, but their characteristics would not have an independent effect on production decisions (in our case, water use).

[5] To test if the set of identifying of identifying instruments are 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 the measure of goodness-of-fit of the regression of the residues from the institutional equation (2) on the variables which are exogenous to the system. The test statistics are 0.00 for WUAs, 0.05 for contracting, 1.36 for non-collective with incentives and 2.27 for non-collective without incentives. The test results indicate the null hypothesis that there is no correlation between the exogenous instruments and the disturbance term from institutional equation (2) cannot be rejected.

explanation for the difference between yields and income may be due to the fact that water fees also fall 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. Econometric analysis was used to isolate the effect of reform on income. Econometric analysis was also used to distinguish between income and poverty effects; in contrast to the case of income, our descriptive data show that poverty is worse in those villages that provide managers with incentives (row 6).

Multivariate Empirical Model and Results

In addition to water management reform, other socio-economic factors also influence agricultural production, income, and poverty. In order to answer the question of whether water management reform affects outcomes, it is necessary to control for these other factors.

To do so, we specify the link between agricultural production and its determinants as:

$$Q_{ijk} = ? \ ? \ ? W_{ijk} \ ? \ ?X_{ijk} \ ? \ ?Z_{ijk} \ ? \ D_{ijk} \ ? \ ?_{ijk} \qquad (3)$$

where Q_{ijk} represents the yields of wheat, maize or rice from the *i*th plot of household *j* in village *k*. In equation (3), yields are explained by the variable of interest, W_{ijk}, which measures water use per hectare, X_{ijk}, which measures other inputs to the production process, Z_{ijk} which holds other factors constant, including characteristics of the production envirnonment of the village, household and plot, and the irrigation district dummy, D_k. Agricultural production inputs include measures of per hectare use of labor (measured in man-days), fertilizer (measured in aggregated physical units[6]) and expenditures on other inputs, such as fees paid for custom services. The control variables for village and household characteristics are the same as for equation (1) except we do not use the village level cropping structure. We also add five plot characteristics, including measures of: soil types; plot location (distance from the plot to the farmer's house); whether the crop on the plot is planted in rotation with another crop or not (*single season* equals one, if not); and production shocks (measured as yield reduction on a plot due to floods, droughts or other "disasters").

The impact of water management reform is measured through the water use variable. If production responds positively to water use, then we can deduce that water management reform will have an effect in the opposite direction, because of its water reducing effect found in Table 5. However, because Table 5 combined all crops together at the household level and in our production analysis wheat, maize and rice are examined separately at the plot level, we need to have separate measures of the effect of water management reform on water use by crop. The results of these alternative water use equations are included in appendix D and show that in the case of all crops, the coefficient on the variable measuring the presence of incentives in local water management institutions is negative (and is significantly so for wheat and rice).[7] Predictions from Appendix D are used in the estimation of equation (3).

We also establish the following equation to examine the relationship between income and other factors:

$$y_{jk} = ? \ ? \ M_{jk} ? \ ? \ Z_{jk} ? \ ? \ D_{jk} \ ? \ ?_{jk} \qquad (4)$$

where y_{jk} represents either total or cropping income per capita or total income per capita for household *j*, and the other variables, including M_{jk}, our interested variable (a measure of incentives) are the same as in equation (1). In examining the effect of water management reform on poverty, we proceed in a similar manner. Because we are measuring poverty in terms of income, one would use primarily the same specification and expect similar results, albeit with opposite signs.

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[6] To measure fertilizer, we decomposed each type of fertilizer by nutrients, N, P and K, and then summed across nutrients and fertilizer types. We also aggregated fertilizer by value and our main results of interest do not change.
[7] The analysis uses plot level data for estimating the equation in Appendix D. We also use predicted values of water management reform for the estimation of the equations in Appendix D because of our concerns of endogeneity.

Almost all the models specified on production, income and poverty perform well and produce robust results that largely confirm our *a priori* expectations (Tables 7 to 9). The goodness of fit measure for production and income models, the adjusted R^2, arrange from 0.16 to 0.40. Many coefficients of our control variables in these models were of expected sign and statistically significant. For example, the production shock not only negatively influences agricultural production, but also reduces farmer income and adversely affects the household's poverty status. Higher levels of landholdings also positively affect incomes.[8]

Our results show that reforming water management reduces wheat yields while it has no significant impact on the yields of maize and rice. From the wheat water use model, when villages provide water managers with incentives, managers reduce water use per hectare about 3800 cubic meter, a decline of about 50 percent (Append D, column 1, row 1). At the same time, the coefficient on the predicted water use variable in the wheat yield equation is positive and statistically significant (Table 7, column 1, row 1). The estimated water use elasticity for wheat yield is 0.226. Overall, our estimates of the size of the decline in water use and the responsiveness of wheat yields to water use imply that water management reform reduces wheat yields by about 11 percent. In contrast, although we find that incentives have a negative association on water use, the estimated water use elasticities for maize and rice are not significantly different from zero (Table 7, columns 2 and 3, row 1).

Results from our plot level analysis of water management and production indicate that in our sample areas the main tradeoff between the water savings from management reform and production occurs for wheat and is less severe or absent for maize and rice. The conclusion is plausible and, although its validity may hold only for our sample region, it is consistent with many of the observations made in the field. Wheat is the crop that depends more than any other on irrigation because its growth period is almost entirely during the dry season. Water cutbacks should be expected to reduce yields. Maize, in contrast, is grown during the wet season and water managers that have an incentive to save water may be able to time their use of irrigation water with the rains while those that have no interest in saving water might adhere to a predetermined water delivery schedule, no matter what the weather. In the case of rice, although the crop is dependent on large volumes of irrigation water, experiments by domestic and international water scientists have shown that there are many new ways of managing rice irrigation (e.g. alternative wetting and drying – see Barker et al, 2002) that can lead to water savings but do not have significant yield effects in many cases. New water management technologies, however, require effort to learn and implement. Our results may demonstrate that it is managers with incentives that have been able and willing to use these new technologies that have brought water savings without large yield declines.

Our research results also demonstrate that water management reform has no impact on farmer income status (Tables 8 and 9). When we use either OLS or 2SLS approaches, the incentive variable in both total and cropping income models is not statistically significant. Consistent with the descriptive statistics (which find no obvious fall in income in those villages that give water managers incentives), our results may suggest that whatever negative income effect there is from falling wheat production, it is being offset partially by reductions in water fees (water fees on average drop by around nine percent). It could also be that the average reduction in income due to lower wheat yields are small enough, 89 yuan (11 percent of average wheat yield, 4740 kg per hectare, times farm size, 0.17 hectare, times the price of wheat, 1 yuan per kg) that they can not be detected statistically. Moreover, since the fall in household income is less than 1.2 percent, the losses in cropping likely are being offset by other actions taken by households (e.g. because water management is better, they can focus more on other economic activities).

The similar results also can be found in the poverty model. Since we measure poverty status as "under the poverty line or not," our results say that there is no effect of a village's decision to provide water managers with incentives on a household poverty status. If universally true, such a

[8] Although the coefficients on the fertilizer variable in the maize and rice yield equations are positive, significant and similar to results found elsewhere in the literature (e.g., Putterman and Ciacu, 1995), as found in much of the literature on cross section production analysis at the household level, our other coefficients are insignificant due to measurement problems (e.g., we observe labor days, not effort), multicollinearity (e.g., when farmers use high levels of one input, they often use high levels of all other inputs), and endogeneity (management ability and weather shocks are not measured completely).

finding would be important, since critics of water management reforms often point out that one possible adverse consequence of using incentives to induce water reform is that managers may cut back on water deliveries to marginal users, who may also be those on the poorest land. Our results here, however, should be interpreted with caution. First, it has not been identified clearly what conditions may be behind this result. In many villages, leaders have specified strict rules in the agreements with water managers that they cannot exclude households from water allocation schedules. Second, as seen by examining the estimated equations in Table 9, only a few of the coefficients are significant, a sign the our sample may be too small to identify poverty effects. In short, while interesting, we believe our current results may be more important in raising awareness of possible associations rather than as definitive. Future research should try to pinpoint the source of this effect and use larger data sets to strengthen our understanding of these issues.

Conclusions

In this paper, we have sought to understand evolution of China's surface water management systems and their effect on water use, output, income and poverty. Research results show that since 1990, and especially after 1995, collective management has been replaced by non-collective, WUAs or contracting systems. In some regions, non-collective management forms even have become the dominant pattern. Innovation of water management has reflected many stakeholders' interests, such as upper and local governments, village leaders and farmers. In particular, policy makers' interventions in the reform process seem to play an important role that made the spatial variation of the reform.

Designing the reform is one issue, implementation is another issue. Despite whether the reform has been designed well as considered by governments, effectively implementing the reform appears to be out of policy makers' control and should be highly emphasized. The major difference between non-collective and collective is the incentives faced by managers. Proving the importance of incentives mechanism for water management is one of our important results. Research show that if managers are provided with positive incentives to earn money by saving water, they will try to improve water management, water delivered to farmers will be significantly reduced. More importantly, our analysis found that even water management with incentives will reduce water use; it will not produce negative impacts on farmers' output (except for wheat), income and poverty. Although this results need to be further explored for possible long term impacts, at least in the short term, the concern on potential negative impacts of water management reform seems to be unnecessary.

Overall, we propose that the government should continue to support the water management reform process. However, different from the initial stage, more emphasis should be put on the effective implementation of the reform. Although the negative impact on farmers have not been found in the short term, in the long term, the government still needs to focus on this issue and take some measures to promote the healthy development of water management reform. Since reform will lead to water savings under the directives of policy makers' design, the scope of how much water should be saved and how to efficiently reallocate the saved water to other water short regions that can maximize social benefits are two important issues that need to be further explored by researchers and policy makers.

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Table 1. Surface water management in the sample villages, in 4 selected irrigation districts, 1990 – 2001

	Ningxia		Henan		Total
	ID-1	ID-2	ID-1	ID-2	
1990			(percent)		
Collective	100	81	100	100	91
WUA	0	5	0	0	3
Contracting	0	14	0	0	6
1995					
Collective	100	72	100	100	87
WUA	0	10	0	0	6
Contracting	0	18	0	0	7
2001					
Collective	27	51	92	100	64
WUA	50	14	0	0	14
Contracting	23	35	8	0	22

Data source: Authors' survey

Table 2. Incentives mechanism of WUA and contracting in the sample irrigation districts, 2001

	Percentage of samples (%)		
	With incentives	Without incentives	Total
Whole samples			
WUA and Contracting	41	59	100
Ningxia Province			
ID-1			
WUA	25	75	100
Contracting	0	100	100
ID-2			
WUA	25	75	100
Contracting	76	24	100
Henan Province			
ID-1			
Contracting	0	100	100

Data source: Authors' survey

Table 3. Relationship between surface water management and crop water use in the sample irrigation districts, 2001

	Crop water use (M^3/ha)
Ningxia Province	
ID-1	
Collective	21294
WUA	23460
Contracting	30969
ID-2	
Collective	16549
WUA	15483
Contracting	11351
Henan Province	
ID-1	
Collective	13052
Contracting	17113
ID-2	
Collective	8450

Data source: Authors' survey

Table 4. Relationship between incentives mechanism and crop water use in the sample irrigation districts of Ningxia Province, 2001

	Crop water use (m^3/ha)		
	Non-collective with incentives	Non-collective without incentives	Collective
Ningxia Province			
Whole samples	12729	20598	14003
ID-1	25055	26583	21924
ID-2	11188	14711	16549
Wheat	5619	7416	7489
Maize	7004	7704	7266
Rice	31307	31688	36949

Data source: Author's survey

Table 5 Determinants of crop water use at the household level

	Water use per hectare			
	OLS	OLS	2SLS	2SLS
Water management institution				
Share of WUA	-1,311.036 (0.70)		-1,919.85 (1.00)	
Share of contracting	-703.677 (0.49)		-2,468.59 (1.34)	
Share of non-collective with incentives [a]		-2,843.730 (1.72)*		-6,355.798 (1.99)**
Share of non-collective without incentives [a]		275.206 (0.18)		1,107.587 (0.43)
Production environment				
Share of village surface water irrigation	2,390.651 (0.99)	2,141.794 (0.90)	2,560.45 (1.08)	2,494.746 (1.06)
Dummy of village water scarcity (1 yes 0 no)	-3,574.071 (3.13)***	-3,811.787 (3.34)***	-3,463.46 (3.03)***	-3,533.920 (3.13)***
Village irrigation investment per hectare	-0.107 (1.01)	-0.055 (0.52)	-0.114 (1.11)	0.032 (0.23)
Cropping structure				
Share of village rice area in 1995	10,592.172 (4.18)***	10,430.425 (4.17)***	10,655.04 (4.23)***	10,437.281 (4.18)***
Household characteristics				
Age of household head	519.380 (1.17)	447.423 (1.02)	551.829 (1.25)	517.174 (1.18)
Squared age of household head	-6.282 (1.28)	-5.610 (1.15)	-6.705 (1.37)	-6.296 (1.29)
Education of household head	-81.947 (0.50)	-78.691 (0.48)	-79.195 (0.48)	-58.589 (0.36)
Arable land per hectare of household	-10,486.693 (2.23)**	-7,920.360 (1.64)	-8,964.48 (1.89)*	-6,326.932 (1.26)
Constant	14,261.399 (1.43)	15,130.403 (1.53)	13,821.54 (1.39)	12,514.529 (1.27)
Observations	189	189	189	189
Adjusted R-squared	0.44	0.45	0.45	0.45

Absolute value of t statistics in parentheses; coefficients of irrigation districts are omitted
[a] Non-collective institutions include WUA and contracting
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6 Incentives, production, income and poverty in the sample irrigation districts, Ningxia and Henan Province, 2001

	Non-collective with incentives	Non-collective without incentives	Collective
Wheat yield (kg/ha)	4340	4827	4800
Maize yield (kg/ha)	5328	6031	5801
Rice yield (kg/ha)	6288	6499	7155
Income (yuan)	2334	1966	1646
Cropping income (yuan)	1073	784	726
Poverty incidence (%)	11.1	6.5	7.5

Data source: Authors' survey

Table 7 Determinants of crop yield (2SLS)

	Log of crop yield per hectare		
	Wheat	Maize	Rice
Production input			
Log of water use per hectare[a]	0.226 (3.15)***	0.043 (0.32)	0.148 (1.05)
Log of label use per hectare	-0.009 (0.26)	0.099 (1.51)	-0.003 (0.07)
Log of fertilizer use per hectare	0.020 (0.44)	0.110 (1.75)*	0.182 (2.53)**
Log of other production fee per hectare	-0.001 (0.09)	-0.002 (0.21)	0.018 (1.49)
Production environment			
Share of village surface water irrigation	0.197 (2.39)**	-0.027 (0.13)	0.103 (0.62)
Dummy of village water scarcity (1 yes 0 no)	0.086 (1.63)	0.029 (0.23)	0.133 (1.38)
Village irrigation investment per hectare	0.000 (0.51)	0.000 (1.18)	0.000 (2.21)**
Household characteristics			
Age of household head	-0.028 (1.74)*	-0.020 (0.76)	-0.029 (1.04)
Squared age of household head	0.000 (2.13)**	0.000 (0.85)	0.000 (0.77)
Education of household head	0.023 (3.04)***	0.006 (0.55)	-0.016 (1.45)
Plot characteristics			
Dummy of loam soil (1 yes 0 no)	0.081 (1.75)*	0.137 (1.80)*	0.077 (1.16)
Dummy of clay soil (1 yes 0 no)	0.095 (2.04)**	0.154 (2.08)**	0.039 (0.60)
Distance to home	-0.008 (0.24)	0.016 (0.25)	-0.016 (0.49)
Dummy of single crop (1 yes 0 no)	0.061 (0.82)	-0.010 (0.09)	-0.029 (0.13)
Production shock			
Yield reduction due to production shock	-1.411 (10.37)***	-1.026 (4.94)***	-1.469 (7.45)***
Constant	6.365 (7.96)***	7.310 (4.73)***	6.698 (4.27)***
Observations	234	158	113
Adjusted R-squared	0.40	0.16	0.37

[a]predicted water use by the determinants of water use model (Appendix D)
Absolute value of t statistics in parentheses; coefficients of irrigation districts are omitted

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 8 Determinants of farmer income

	Total income per capita		Cropping income per capita	
	OLS	2SLS	OLS	2SLS
Water management institution				
Share of non-collective with incentives [a]	175.109 (0.53)	688.980 (1.08)	-136.262 (1.06)	69.719 (0.28)
Share of non-collective without incentives[a]	-18.277 (0.06)	-108.274 (0.21)	-61.382 (0.54)	-95.177 (0.47)
Production environment				
Share of village surface water irrigation	337.665 (0.73)	301.020 (0.66)	-112.871 (0.62)	-125.975 (0.70)
Dummy of village water scarcity	157.467 (0.70)	144.952 (0.66)	-15.764 (0.18)	-3.154 (0.04)
Village irrigation investment per hectare	0.069 (3.37)***	0.056 (2.08)**	0.012 (1.54)	0.007 (0.65)
Cropping structure				
Share of village rice area in 1995	198.901 (0.41)	198.012 (0.41)	-56.991 (0.30)	-59.428 (0.32)
Household characteristics				
Age of household head	183.491 (2.13)**	178.580 (2.07)**	49.640 (1.48)	51.933 (1.53)
Squared age of household head	-1.759 (1.84)*	-1.710 (1.79)*	-0.587 (1.57)	-0.609 (1.62)
Education of household head	21.984 (0.70)	19.876 (0.63)	-7.920 (0.65)	-8.093 (0.66)
Arable land per hectare of household	3,291.145 (2.99)***	3,034.111 (2.71)***	3,270.769 (7.48)***	3,167.299 (7.07)***
Production asset per capita	0.111 (3.49)***	0.110 (3.45)***		
Agricultural production asset per capita			0.081 (1.76)*	0.080 (1.74)*
Number of plots per household	-124.052 (3.68)***	-127.845 (3.79)***	-3.112 (0.24)	-7.441 (0.56)
Production shock				
Dummy of production shock	-229.269 (1.23)	-219.720 (1.18)	-183.171 (2.52)**	-180.501 (2.47)**
Constant	-2,707.916 (1.41)	-2,458.543 (1.29)	-472.618 (0.63)	-459.997 (0.61)
Observations	189	189	189	189
Adjusted R-squared	0.24	0.25	0.35	0.35

Absolute value of t statistics in parentheses; coefficients of irrigation districts are omitted

[a] Non-collective institutions include WUA and contracting

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 9 Determinants of poverty

	Dummy of poverty	
	OLS	2SLS
Water management institution		
Share of non-collective with incentives[a]	0.086	0.057
	(1.21)	(0.41)
Share of non-collective without incentives[a]	0.032	-0.040
	(0.52)	(0.36)
Production environment		
Share of village surface water irrigation	-0.175	-0.167
	(1.75)*	(1.68)*
Dummy of village water scarcity (1 yes 0 no)	0.001	-0.008
	(0.03)	(0.16)
Village irrigation investment per hectare	-0.000	-0.000
	(1.07)	(0.85)
Cropping structure		
Share of village rice area in 1995	0.012	0.018
	(0.12)	(0.17)
Household characteristics		
Age of household head	0.007	0.009
	(0.40)	(0.45)
Squared age of household head	-0.000	-0.000
	(0.53)	(0.60)
Education of household head	-0.009	-0.010
	(1.39)	(1.40)
Arable land per hectare of household	-0.297	-0.261
	(1.24)	(1.07)
Production asset per capita	-0.000	-0.000
	(0.76)	(0.72)
Number of plots per household	0.012	0.013
	(1.70)*	(1.83)*
Production shock		
Dummy of production shock (1 yes 0 no)	0.095	0.095
	(2.36)**	(2.33)**
Constant	0.083	0.087
	(0.20)	(0.21)
Observations	189	189
Adjusted R-squared	0.01	0.01

Absolute value of t statistics in parentheses; coefficients of irrigation districts are omitted
[a]Non-collective institutions include WUA and contracting
* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix A: Calculation of crop water use

At first, we checked the variable of water use per irrigation by crops estimated by canal managers and village leaders, then we averaged their information to estimate average water use per irrigation by crops in the village. According to our survey, nearly 80 percent of village leaders and canal managers can give a relatively accurate estimation on this number which are generally consistent with local officials' estimation or their experimental results. If existing some heretical data, we will adjust them by the secondary source data and other villages' estimation those having similar physical and water conditions. For the rest of the villages where it is hard to estimate water use by crops, they can provide the information on irrigation hours per *mu* and water depth in the field by crops. Since this information are also provided by those villages that have water use estimation, we will compare this information and then get an estimation of water use per irrigation by crops if these villages have similar physical and water conditions. Finally, each village will get one estimation on average water use per irrigation by crops. We apply this information to each sample household and multiply it by irrigation times of crops per year in certain land plot answered by farmers and then get annual total water use in the sample land plots of farm households. Household average water use of certain crops is the average of water use of all the plots that plant this crop.

Appendix B Statistic Description of 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 non-collective with incentives	0.16	0.36	0	1
Share of non-collective without incentives	0.20	0.39	0	1
Dummy of governmental intervention for WUA	0.14	0.35	0	1
Dummy of governmental intervention for Contracting	0.30	0.46	0	1
Age of village leader (year)	43	7	29	55
Education of village leader (year)	9	3	0	15
Share of village surface water irrigation	0.73	0.41	0	1
Dummy of village water scarcity	0.27	0.45	0	1
Village irrigation investment (yuan/ha)	2824	4881	0	33943
Share of village rice area in 1995 (%)	0.19	0.21	0	0.80
Household crop water use per hectare (m^3/ha)	15365	8739	627	44580
Wheat water use per hectare (m^3/ha)	5937	3909	300	21000
Maize water use per hectare (m^3/ha)	6936	4802	360	27750
Rice water use per hectare (m^3/ha)	28882	18572	1381	89072
Household total income (yuan)	1855	1426	-42	11087
Household cropping income (yuan)	806	604	-135	4285
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
Arable land per hectare of household (ha)	0.17	0.12	0.03	1.03
Production asset per capita (yuan)	1434	2972	2	32533
Agricultural production asset per capita (yuan)	906	857	1	4800
Number of plots per household (number)	7	4	1	23
Dummy of production shock	0.52	0.50	2	1
Wheat yield (kg/ha)	4740	1253	375	8625
Maize yield (kg/ha)	5760	1770	600	10125
Rice yield (kg/ha)	6900	1740	1125	12855

Data source: Authors' survey

Appendix C Determinants of water management institution at the village level

	(1)	(2)	(3)	(4)
	Share of WUA	Share of contracting	Share of non-collective with incentives [a]	Share of non-collective without incentives [a]
Water policy				
Dummy of governmental intervention	0.864 (22.43)***	0.670 (7.72)***	0.212 (2.10)**	0.424 (4.53)***
Characteristics of village leaders				
Age of village leader	0.000 (0.21)	-0.017 (3.32)***	-0.013 (1.80)*	-0.003 (0.47)
Education of village leader	0.002 (0.45)	-0.005 (0.37)	-0.029 (1.43)	0.021 (1.13)
Production environment				
Share of village surface water irrigation	0.004 (0.08)	0.182 (1.23)	-0.078 (0.38)	0.263 (1.39)
Dummy of village water scarcity (1 yes 0 no)	-0.001 (0.06)	0.086 (1.16)	0.015 (0.15)	0.060 (0.63)
Village irrigation investment per hectare	0.000 (10.43)***	0.000 (0.54)	0.000 (2.40)**	0.000 (0.28)
Cropping structure				
Share of village rice area in 1995	0.016 (0.27)	-0.051 (0.32)	-0.055 (0.25)	0.043 (0.21)
Observations	51	51	51	51
Adjusted R-squared	0.94	0.65	0.23	0.42

Absolute value of t statistics in parentheses; coefficients of irrigation districts are omitted

[a] Non-collective institutions include WUA and contracting

* significant at 10%; ** significant at 5%; *** significant at 1%

Appendix D Determinants of crop water use at the plot level

	Water use per hectare		
	Wheat	Maize	Rice
Water management institution			
Share of non-collective with incentives[a]	-3,802.375 (2.83)***	-2,107.654 (1.09)	-23,149.103 (2.24)**
Share of non-collective without incentives[a]	-1,054.236 (0.96)	992.491 (0.63)	-5,943.309 (0.64)
Production environment			
Share of village surface water irrigation	61.923 (0.06)	-1,555.108 (0.64)	1,018.291 (0.10)
Dummy of village water scarcity	-1,911.910 (3.90)***	-3,510.065 (4.45)***	-11,202.815 (2.75)***
Village irrigation investment per hectare	0.110 (1.79)*	0.090 (1.02)	-1.948 (1.83)*
Cropping structure			
Share of village rice area in 1995	-3,210.399 (2.79)***	-1,106.899 (0.54)	11,146.211 (0.96)
Household characteristics			
Age of household head	29.091 (0.16)	-251.383 (0.84)	2,779.020 (1.68)*
Squared age of household head	-0.560 (0.28)	2.725 (0.82)	-32.915 (1.80)*
Education of household head	-198.481 (2.91)***	-144.878 (1.31)	-687.514 (1.18)
Arable land per hectare of household	-218.531 (0.10)	-5,470.061 (1.76)*	25,745.862 (1.61)
Plot characteristics			
Dummy of loam soil	347.962 (0.66)	-309.517 (0.36)	1,619.001 (0.38)
Dummy of clay soil	358.484 (0.68)	-44.854 (0.05)	1,204.337 (0.29)
Distance to home	-51.871 (0.15)	1,119.131 (1.57)	190.460 (0.10)
Dummy of single crop	841.530 (1.04)	1,429.926 (1.25)	-2,000.727 (0.15)
Constant	12,469.815 (3.00)***	18,713.794 (2.64)***	-3,738.899 (0.10)
Observations	234	163	114
Adjusted R-squared	0.41	0.31	0.30

Absolute value of t statistics in parentheses; coefficients of irrigation districts are omitted
[a]Non-collective institutions include WUA and contracting
* significant at 10%; ** significant at 5%; *** significant at 1%