Institutional Reform and Impacts: The Case Study in the Yellow River Basin

Jinxia Wang[1], Zhigang Xu[1], Jikun Huang[1], and Scott Rozelle[2]

1. International Water Management Institute (IWMI) and Associate Professor of Center for Chinese Agricultural Policy (CCAP), Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China
2. Department of Agicultural and Resource Economics, University of California, Davis

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 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 incentive 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 57 villages, 231 farmers and 462 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, individual water contractors, have begun to systematically replace traditional forms 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 manager strong incentive to save water. Specifically, when managers in reformed organizations face strong incentive, they save water and, 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, Collective Management, Water User Associations, Contracting, Incentive, Impacts

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). Shortages of water are attenuating efforts to alleviate poverty and are becoming a major source of environmental problems (World Bank, 1998; Zhang, 2000). In many regions of the country rapidly growing industry and an expanding, increasingly wealthy urban population regularly outcompete 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 they should the use to address water scarcity problems, although none has been very successful (Wang, Huang and Rozelle, 2000). Developing more water resources to increase water supply has historically been given the highest priority in resolving water shortage problems. Since the 1950s, China's government has invested more than 127 billion US dollars into constructing infrastructure for developing 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 north 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 still be marginal. Leaders also have promoted water saving technology and considered whether or not they should use water pricing policy (Chen, 2002; Rosegrant and Cai, 2002). Unfortunately, most of their 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). Political considerations also most likely will keep leaders from moving too agressively on raising 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--but especially those in agriculture, by far the nation's largest consumer of water--do not efficiently use the water that they are allocated One study, for example, estimated that due to the poor management of the nation's canal network, only 50 percent of water from the main canal channels are 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, overall, only about 40 percent of water in China's surface water system that is allocated to production agriculture is actually used by crops. Others have estimated even greater inefficiencies (Fang, 2000). In response, it has been proposed that local leaders reform the institutions that manage water in China's communities (Nian, 2001; Reidinger, 2002).

Despite the resolve of the current leadership in China to push water management reform, there is considerable debate about its appropriateness. International evidence shows that water management and its institutional arrangements are important measures for dealing with water shortage problems (World Bank, 1993; IWMI and FAO, 1995). Since the 1980s, many developing countries and some developed ones 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 (IWMI, 1997). However, there are many cases internationally when these efforts have failed (Vermillion, 1997).

In fact, since as early as the 1980s, but even more so since 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 only based on 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 incentive right may be among the most important reasons that water management reform has failed in some places. In addition, considering the premise of the way that reformed water institutions are supposed to deliver water to farmers—providing incentive to individual to more efficiently manage water—there are a number of reasons that new water managers could take actions (e.g., cut off water deliveries to slow-paying poor households) that could negatively affect the income and the poverty status of certain individuals. Surprisingly, despite the high stakes of the reforms there is little or no empirical-based work that has been conducted to understand and judge the effectiveness of water management reform.

The overall goal of our paper is to better understand water management reform in China's water-short rural communities, 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 incentive 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.

Data

The data for our study come from a survey that we conducted in 57 villages in four irrigation districts (IDs) of 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). In selecting the irrigation districts for our study, we considered a number of criteria. From a number of IDs in each province, we chose the two IDs based mostly 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 selected 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 five 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 57 villages leaders, 59 water managers, 231 farm households and gathered information on 462 plots of their plots.

In order to reach 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 management patterns were identified: collective management, Water User Associations (WUAs) and contracting. From our village and canal management questionnaires we recorded the share of canals within the each village that is controlled by each type of management form 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), they face *strong incentive*. If their incomes from their

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

water management duties are not connected to water savings, they are said to face *weak incentive*. During the household level survey, we also asked farmers about the managers of the canals that service their plots.

The survey also collected information that we use to develop several measures of the effects of water management reform—water use, production and income. In order to get relatively accurate measures of water use, which in surface water systems is typically difficult to elicit, we adopted the strategy to ask all of those that were involved in the irrigation scheme: farmers, water managers and village leaders. When talking to water users, we also asked about crop water use 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).

Beside measures of water management reform and water use, 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 a 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 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 reform in their villages. A number of other questions asked about the reliability of the irrigation system (e.g., "how many times during the past calendar year did you need water but it was not available), the level of investment in the village's irrigation system, as well as a number of other household, land plot and village characteristics. Descriptive statistics (means, standard deviation, minimum and maximum) of the main variables are shown in Appendix B.

Reform and the Evolution of Water Management

Based on our field survey, after reform villages manage surface water in three general ways: collective management, Water User Associations (WUAs) and contracting. If the village leadership through the village committee takes responsibility for water allocation, canal operation and maintenance (O&M) and fee collection, the village's irrigation systems is said to be governed by *collective management*, the system that essentially has been allocating water in most villages during the People's Republic period. *WUA* is a system that, in theory, is a farmer-based organization that is set up to manage the village's water. In WUAs a member-elected board is proposed to be assigned the control rights over the village's water. *Contracting* is a system in which the village leadership establishes a contract with an individual to manage the village's water. In addition to control rights, water management reform also seeks to provide incentive to the water manager. Managers with strong incentive earn the difference between the fixed revenues that are associated with a village's land (the total area times a per hectare water fee, which is set by upper-level officials) and the amount of money that that has to be remitted to the irrigation district. The remittance from the water manager to the ID is based on the actual volume of water used. The managers earn more income if they can reduce the volume of water that farmers use (subject to ensuring the village's cropping activities are not adversely affected in any major way).

According to our data, since the early 1990s and especially after 1995, reform has successively established WUA 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.[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. Contractors managed water in approximately 50 percent of the villages and WUAs managed about 23 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 WUAs or contracting (columns 3 and 4).

Based on our field survey, although some of the differences in water management among these IDs may be due to the characteristics of local villages and local water management initiatives, the dramatic differences between Ningxia and Henan Provinces suggests 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 official 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 relax the constraints that were holding back) reform.

The differences among the villages in Ningxia and differences in the way that different regions implement the reforms (i.e., some move to contracting while others shift to WUAs), however, 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. 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-levels of government, when local leaders set up their organizational frameworks in their villages, practice often varies substantially 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 form 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

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

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 WUA. In many of these WUAs that had village-appointed leaders, however the main managers actually had close ties to the village, more than half either being an individual that had previously been a leader. In other words, at least in terms of the composition of the management team, most WUAs differ little from collective management.

There are also sharp differences in the way that villages have implemented the incentive part of the reform packages, regardless of whether they use WUAs or contracting (Table 2). For example, in 2001, on average, in only 54 percent of villages did leaders offer contracting managers with incentive that could be expected to induce managers to exert effort to save water in order to earn a profit (row1). In the rest of the villages, although there was a nominal shift in institutions (that is leaders claimed that they were implementing WUAs or contracting), in fact, from an incentive point of view, the managers involved in WUAs and contracting faced poor or no incentive in a way similar to those faced by village leaders in collective management (row 1). The incentive offered the managers also differ across IDs (rows 2 to 6). Hence, to the extent that the incentive are one of the most important parts of the reforms, the difference across time and space in terms of the nature of the incentive faced by managers means that it would not be surprising if in some cases WUAs and contracting were more effective than other cases.

Water Management and Crop Water Use

Although the main objective of water management reform is to save water, descriptive statistics using our data show that water use in some areas that have established WUAs and contracting is lower than those areas still under collective management, but higher in others (Table 3). For example, in the second ID in Ningxia (ID2), the water use per hectare in areas that have reformed is lower than those areas in which the collective still manages the water (rows 4 to 6). However, in Ningxia's other ID (ID1) and in Henan, water use per hectare is higher in those villages that shifted to WUAs or contracting (rows 1 to 2, 7 and 8).

While the effectiveness of reform is not clear when examining water use by ID, our data show the importance of policy implemention. In particular, the importance of incentive in making reform work is shown when examining water use in those villages that provided their water managers with strong incentive versus those in which managers faced poorer or no incentive (Table 4). When managers face strong incentive to earn profit by saving water, average crop water use per hectare fell by about 40 percent (row 1). We also find a positive impact of incentive on water savings when examining either WUAs or contracting separately. For example, in one of the IDs in Ningxia Province, when officials provided WUA managers with strong incentive, crop water use per hectare fell by 46 percent; when private contractors faced strong incentive, crop water use fell by 8 percent (rows 2 and 4).

While our descriptive analysis shows that there is a positive correlation between strong incentive and water savings, in fact, there could be many other factors that are correlated with incentive that are creating the tendency of incentive and water savings to move together. In particular, it could be that cropping structure, the nature of the canal system's investment, and the scarcity of water may affect both the managerial form 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

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

$$w_{jk} = \alpha + M_k \beta + Z_{jk} \gamma + D_{jk} + \varepsilon_{jk} \quad (1)$$

where w_{jk} represent average crop water use per hectare for household j in village k. The rest of the variables are those that explain water use: M_k, our variable of interest, measures either the form of the water management institution in the village or the nature of the incentive faced by water managers; Z_{jk} represents other village and household factors that affect water use. For example, we include a number of variables to hold constant the nature of the household's production environment, such as the conditions of the local irrigation system and the cropping structure. The variables that measure the quality of the village's irrigation system include the source of water (either surface or ground), the degree of water scarcity and the level of irrigation investment per hectare. Finally, our model also includes D_{jk}, a dummy variable representing the ID that serves the household . The symbols α , β and γ are parameters to be estimated, and ε_{jk} is the error term, which 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 crop water use model (Table 5). The goodness of fit measure, the adjusted R^2, around 0.50, is sufficiently high for analyses that use cross sectional household data. Many coefficients on our control variables have the expected sign and are statistically significant. For example, we find that after holding constant other factors, households use less water when their plots rely on groundwater rather than surface water. We also find that those villages that face more severe water shortages use less water per hectare.

After keeping constant other factors, managers in those areas that have experienced water management reform significantly reduce water use per hectare when compared to those villages under the collective management, a result that is particularly true for contracting. Specifically our analysis demonstrates that compared with collective management, contracting saves crop water use by more than 3000 cubic meters per hectare (Table 5, column 1, row 6). The sign on the WUA variable also is negative; the point estimate of our analysis shows that when a village manages their water through a WUA, farmers also tend to reduce crop water use per hectare when compared to collective management (row 2). However, unlike the coefficient on the contracting variable, the standard error is relatively larger, perhaps impling that contracting generally has been more effective than WUAs. Unfortunately, examining the coefficients on the institutional form indicator variables tell us nothing about why one reform institution would out perform another.

Our analysis provides insight regarding the performance of contracting when we reestimate the model, replacing the form of the water management institution with a variable that measures the strength of the incentive faced by the water manager (Table 5, column 2). We find that when officials provide water managers with strong incentive, regardless of their institutional form, farmers in the village save water. Our econometric results show that the coefficient on the incentive indicator variable is positive and significant at the 1 percent level (when compared to the base, collective management row 1). In other words, without regard to the form of the water management institution, when managers face strong incentive, they reduce water use by nearly 5000 cubic meters of water per hectare. When we examine the relationship between incentive and water use for managers that are contracting seperately from those WUA managers, our findings show that incentive remain important, a result that is esepcially true for contract (column 3).

Although the results are robust to several specifications, it is possible that the estimated parameter is biased since water use per hectare and water management may be determined simultaneously (or that the estimated coefficient is affected by unobserved heterorgeneity). For example, it is possible that in areas that are facing rising demand for water from cities, farmers naturally reduce crop 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 had no effect. In order to control for the potential endogeneity of water management forms and incentive in the water use equation, we adopt an instrumental variable approach. Prior to estimating equation (1), we can regress a set of variables on the water management institution variable, M_k:

$$M_k = \alpha + P_k \beta + Z_k \gamma + \varepsilon_k \qquad (2)$$

where the variableZ_k represents a number of village charateristics and includes. variables that represent land endowments, irrigation conditions, the age of the village leader and the leader's experience in managing water.

The key independent variable in equation (2) that we use to address the endogeneity problem is P_k, a variable 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, 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 intially he went to villages in which he personally knew the local officials. If the spectrum of the aquaintances 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.

Examining the results of equation (2) by itself, the model performs well (Table 6). The logit version of the equation produces pseudo R-squares that range from 0.48 to 0.84. Almost all of the coefficients on the control variables are statistically important. 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.

When putting the predicted value of the water management variable into the crop water use model of equation (1), the results change little and, in fact, by some measures the overall performance improves (Table 5, columns 4 and 5).[3] For example, compared with the incentive variable, the t statistic of the estimated coefficient on the incentive variable rises from 3.31 to 5.68, the results similarly improved when using the form of the water management institution(it is significant at the 1 percent level instead of the 10 percent as in column 1. Generally, our results are robust to our use of OLS or an IV approach.

Water Management, Production, Income and Poverty

Although water management reform, at least when implemented as designed, leads to

[3] Although in equation (2), we show that the water management variable varies at the the village level, since some of households choose not to irrigate their land even when the village has irrigation facilities, , we use household level data to estimate the the predicted value of the water management institution variable.

water saving and meets the primary goal of water sector officials, it is possible that the success from such a policy would only come at a cost, either in terms of falling production, income or increased poverty. In this section, we will examine how water management affects agricultural production, income and the incidence of poverty.

Examing our data show that water management reform will not necessarily negatively influence farmer's welfare. Although statistic description show that after reform, especially in those villages that canal managers are provided with strong incentive, crop yield of wheat, maize and paddy are lower and more poverty occurred, it is not true for farmer's income (Table 7, rows 1 to 3, row 6). Evidence from our survey reveals in villages in which leaders reform their water management system, farmers earn higher income (rows 4 and 5). Generally, under the water management that managers face with strong incentive, farmers' total and cropping income seperately increase by 18 and 13 percent than that under collective management.

Multivariate Empirical Model and Results

Except for water management, farmers' agricultural production, income and poverty are also influenced by many other socio-economic factors; in order to answer the question of whether water management matters for the determination of household agricultural production, income and poverty holding other factors constant (and if so to assess the magnitude of its impact), we use econmetric equations to examine the relationship between agricultural production, income, poverty and their influence factors.

The following equation is the link between agricultural production and its determinants:

$$Q_{ijk} = \alpha + W_{ijk}\beta + Z_{ijk}\gamma + D_{ijk} + \varepsilon_{ijk} \qquad (3)$$

Where Q_{ijk} represents yield of wheat, corn or paddy in the *i*th plot of household *j* in village *k*. The rest of variables are those that explain the crop yield. The variable of W_{ijk}[4] is our interested, representing crop water use in the *i*th plot of household *j* in village *k*. Other controlled variable Z_{ijk} include agricultural production inputs such as per hectare use of labor, fertilizer and other production fees, characteristics of land plots such as soil type, instance to home and cropping structure, production shock, i.e, the yield reduction due to disaster and the vector of household characteristics such as age and education year of household head, production assets.

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

$$y_{jk} = \alpha + M_{jk}\beta + Z_{jk}\gamma + D_{jk} + \varepsilon_{jk} \qquad (4)$$

Where y_{jk} represents cropping income per capita or total income per capita for household *j* in village *k*. The control variable Z_{jk} include irrigation condition, household characteristics, production shock (special for cropping income model) and village characteristics which are special for total income model.

As an alternative, instead of putting water management variable into the equation (4), we also put household water use variable into the equation (4), so the equation (4) has become the following specification:

$$y_{jk} = \alpha + W_{jk}\beta + Z_{jk}\gamma + D_{jk} + \varepsilon_{jk} \qquad (5)$$

[4] When running the 2SLS regression, similar to household level analysis, we also established econometric model of

In examining poverty incidence, we proceed in largely the same way. Because we are measuring poverty in terms of income, one would expect similar results, albeit with opposite signs, from regressions explaining income and those explaining poverty. However, there is not always a one to one correpondence.

Specifically, to study the effect of irrigation on poverty, we begin by defining poverty as a 0-1 variable. In our analysis, $P_{jk} = 1$ if the jth household's total income or cropping per capita, y_{jk} *is* less than the poverty line, Z. With this definition of poverty, we proceed by using estimating framework:

$$\Pr\left\langle P_{jk} = 1 \middle| M_{jk}, Z_{jk}, D_i \right\rangle = \Phi\left(M_{jk}\beta + Z_{jk}\lambda + D_{jk}\right) \qquad (6)$$

Where Φ is the standard cumulative normal distribution, In this model, the definitions of all the variables are the same as in the income equation. Similar to income equation, water management variable in the equation (6) also can be substituted by water use variable and the model is specified as the following:

$$\Pr\left\langle P_{jk} = 1 \middle| W_{jk}, Z_{jk}, D_i \right\rangle = \Phi\left(W_{jk}\beta + Z_{jk}\lambda + D_{jk}\right) \qquad (7)$$

Almost all the models that established on production, income and poverty performed well and produced robust results that largely confirm to a priori expectation For production and income models, the goodness of fit measure, the adjusted R^2, around 0.23-0.34, is sufficiently high for analyses that use cross sectional household data; the Pseudo R^2 of 0.41-0.43 for poverty model is also high enough (Tables 8 to 10). In addition, many coefficients of our control variables in these models were of expected sign and statistically significant (the signs on the coefficients of control variables are generally consistent with expectations). For example, results show that fertilizer is one of important input for production; with the increase of irrigation investment, farmers' cropping and total income will increase; increasing farmer labors' non-agricultural work opportunity not only can increase farmers' income, but also can improve the poverty status.

In multivariate analysis, our results support that of the descriptive statistics. Either in production, income or poverty equation, the coefficient signs of water management or incentive mechanism are all not statistically significant, which is consistent with the expectation (Tables 10 to 15). Instead of water management variables, predicted crop water use per hectare is also directly put into the models and the coefficients are also not significant. It implies that despite the evolution of water management will reduce crop water use, however, water management reform neither has negative effect on farmers' production, income nor worsening farmers' poverty status. Although the results also have not showed that water management reform can improve farmers' welfare condition, from another aspects, under improving water use effeciency and no worsening farmers' welfare is also an important gain from the reform.

Conclusion

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

---

determinants of water management at the plot level and determinants of water use model by wheat, maize and paddy.

spacial variation of the reform.

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

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

References

China Irrigation District Association, 2002. Participatory Irrigation Management: Management Pattern Reform of State-owned Irrigation District. http//www.hwcc.com.cn.

Chen, L. 2002. Revolutionary Measures: Water Saving Irrigation. http//www.Chinawater.net.cn

Fang, SH. 2000. Combined with Allocating and Controlling Local Water Resources to Save Water. Journal of Water Resources, 2000 (1).

Huang, WB. 2001. Reform Irrigation Management System, Realizing Economic Independency of Irrigation District, Participatory Irrigation Management: Innovation and Development of Irrigation System, Edited by Lixin Nian, China Water Resources and Hydropower Publishing House, Beijing, China.

Ma, ZR. 2001. Deepening Reform of Farmer Managed Irrigation System, Promoting Sustainable Development of Irrigation District, Participatory Irrigation Management: Innovation and Development of Irrigation System, Edited by Lixin Nian, China Water Resources and Hydropower Publishing House, Beijing, China.

Management Authority of Shaoshan Irrigation District, 2002. Positively Promoting Reform Based on Practices of Irrigation District, Obtaining Achievement of Both Management and Efficiency, http//www.hwcc.com.cn

Nian, LX. 2001. Participatory Irrigation Management: Innovation and Development of Irrigation System, China Water Resources and Hydropower Publishing House, Beijing, China.

Reidinger, R. 2002. Participatory Irrigation Management: Self-financing Independent Irrigation and Drainage District in China, www.hwcc.com.cn.

Vermillion, DL. 1997. Impacts of Irrigation Management Transfer: A Review of the Evidence, Research Report Series, No 11, International Water Management Institute.

Xu, ZF. 2001. Studying on Increasing Water Use Efficiency, Journal of Water Resources, 2001 (1.)

Zhang, Y. 2001. Carefully Implement the Fifth-conference, Creating the New Situation, Journal of Water Resources, 2001 (1).

Zhang, Y. 2000. Ten Challenges Faced with China Water Resources, Journal of Water Resources, 2000 (1).

Zai, HH. 2002. Speaking on the National Workshop of Water Saving Irrigation, www.hwcc.com.cn.

Wang, JX. 2002. Field Survey Note in Ningxia Province in 2002.

Wang, JX. 2000. Property Right Innovation, Technical Efficiency and Groundwater Management: Case Study of Groundwater Irrigation System in Hebei, China, 2000, Ph.D. Thesis, Chinese Academy of Agricultural Sciences.

Wang, JX, JK.Huang, S. Rozelle, 2000. Property Right Innovation and Groundwater Irrigation Management, Journal of Economic Research, No (4), 2000.

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. Incentive mechanism of WUA and contracting in the sample irrigation districts, 2001

	Percentage of samples (%)	
	Strong incentive	Weak incentive
All samples		
WUA and Contracting	54	46
Ningxia Province		
ID-1		
WUA	75	25
Contracting	0	100
ID-2		
WUA	27	73
Contracting	76	24
Henan Province		
ID-1		
Contracting	0	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	21924
	WUA	23460
	Contracting	30969
ID-2		
	Collective	16549
	WUA	15483
	Contracting	11351
Henan Province		
ID-1		
	Collective	11865
	Contracting	17113
ID-2		
	Collective	8268

Data source: Authors' survey

Table 4. Relationship between incentive mechanism and crop water use in the sample irrigation districts, 2001

	Crop water use (m^3/ha)	
	Strong incentive	Weak incentive
All samples		
WUA and Contracting	14248	20495
Ningxia Province		
ID-1		
WUA	22408	26614
ID-2		
WUA	11555	16912
Contracting	11135	12021

Data source: Author's survey

Table 5. Determinants of household crop water use

	Crop water use				
	OLS	OLS	OLS	2SLS	2SLS
Water management and incentive					
-- Strong incentive			-4966		-10546
			(-3.31)***		(5.68)***
-- Weak incentive			1158		3206
			-0.71		(1.70)*
-- WUA	-2578			-2632	
	-1.28			-1.37	
-- Strong incentive		-4362			
		-1.58			
-- Weak incentive		2107			
		-0.89			
-- Contract	-3129			-3752	
	(1.97)*			(2.30)***	
-- Strong incentive		-5235			
		(2.92)***			
-- Weak incentive		811			
		-0.44			
Irrigation condition					
-- Dummy of groundwater	-2697	-2531	-2525	-2702	-2568
Irrigation (1 yes, 0 no)	(2.54)***	(2.34)***	(2.38)***	(2.56)***	(2.56)***
-- Dummy of water scarcity	-3310	-3625	-3641	-3258	-2489
(1 yes, 0 no)	(3.62)***	(4.04)***	(4.05)***	(3.61)***	(3.02)***
-- Irrigation investment per hectare	-0.01	0	0	-0.01	-0.08
	-1.1	-0.19	-0.06	-1.63	-1.65
Cropping structure					
-- Share of paddy	11381	10580	10531	11653	10907
	(4.84)***	(4.70)***	(4.66)***	(4.86)***	(4.73)***
Dummy of irrigation district					
-- Ningxia Province ID-2	-10103	-9472	-9581	-9969	-9993
	(6.15)***	(5.88)***	(6.67)***	(6.03)***	(6.65)***
-- Henan Province ID-1	-14205	-13752	-13882	-14293	-15070
	(7.57)***	(8.52)***	(8.67)***	(7.35)***	(8.17)***
	-16076	-15444	-15560	-16169	-16922
ID-2	(8.93)***	(9.76)***	(10.08)***	(8.62)***	(9.42)***
Constant	24894	24256	24302	25001	25630
	(15.04)***	(16.82)***	(17.02)***	(14.31)***	(14.96)***
Adjusted R-square	0.48	0.51	0.51	0.48	0.55
F-statistic	24.7	22.42	27.57	25.05	31.88
Samples	231	231	231	231	231

Note: Numbers in brackets represents t statistic test; "*", "**" and "***" separately represents statistic significance at 10%, 5% and 1%。

Table 6 Determinants of water management with logit model at the village level

	WUA	Contract	Strong incentive	Weak incentive
Water Policy				
-- Dumy of Governmental intervention	15.496	10.224	3.278	3.597
(1 yes, 0 no)	(11.83)***	(13.33)***	(19.97)***	(16.68)***
Village characteristics				
-- Per capita area in village	115.879	-2.455	26.795	-16.067
	(8.56)***	-0.99	(19.35)***	(13.38)***
-- Share of labors educated	14.701	-15.984	0.529	-1.874
	(4.90)***	(6.09)***	-0.78	(2.45)**
-- Share of area irrigated conjunctively	21.203	-19.628	0.201	-35.841
	(7.17)***	(5.49)***	-0.51	(7.09)***
-- Share of years with drought	9.28	-5.482	-1.689	0.552
	(7.95)***	(10.38)***	(9.24)***	(3.17)***
-- Distance to town	0.213	-0.016	-0.02	-0.101
	(4.25)***	-0.76	(2.46)**	(9.59)***
-- Farmer income per capita	0.014	-0.007	-0.001	-0.001
	(8.36)***	(11.77)***	(6.76)***	(4.45)***
-- Water fee per hectare in the last year	0.562	-0.167	0.082	-0.073
	(8.01)***	(5.43)***	(13.30)***	(9.09)***
-- Share of grain sown area in the last year	-18.692	0.064	-9.135	7.144
	(7.41)***	-0.03	(12.76)***	(8.37)***
-- Age of village leader	-7.023	0.642	-0.931	-1.38
	(9.75)***	(1.80)*	(9.40)***	(11.19)***
-- Squared age of village leader	0.098	-0.014	0.012	0.014
	(10.21)***	(2.91)***	(10.38)***	(9.60)***
-- Total yeas of being village leader	-0.089	0.223	-0.14	0.306
	-0.62	(5.27)***	(6.59)***	(12.45)***
Constant	46.713	18.858	17.622	29.193
	(4.20)***	(3.45)***	(8.08)***	(11.02)***
Observations	51	51	51	51
LR test	3499	4188	2753	1986
Pseudo R^2	0.84	0.78	0.51	0.48

Note:Numbers in the parentheses are absolute value of z statistics; “*”, “**” and “***” separately represents statistic significance at 10%, 5% and 1%。

Table 7 Incentive, production, income and poverty in the sample irrigation districts, Ningxia and Henan Province, 2001

	Strong incentive	Weak incentive
Wheat yield (kg/ha)	4317	4709
Maize yield (kg/ha)	5578	5964
Paddy yield (kg/ha)	6294	7370
Income (yuan)	2928	2486
Cropping income (yuan)	964	850
Poverty incidence (%)	11.4	5.3

Data source: Authors' survey

Table 8 Determinants of crop yield

	Wheat		Corn		Paddy	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Irrigation condition						
--Dummy of groundwater irrigation	-0.03	-0.01	-0.01	-0.04	0.00	0.02
(1 yes, 0 no)	(0.67)	(0.24)	(0.22)	(0.81)	(0.05)	(0.46)
--Irrigation reliability	0.08	0.10	0.22	0.30	0.02	-0.02
	(1.03)	(1.13)	(1.79)*	(2.94)***	(0.22)	(0.21)
Production input						
--Water use per hectare	0.14	0.14	0.07	-0.02	0.01	0.11
	(5.83)***	(2.30)**	(1.48)	(0.36)	(0.49)	(1.05)
--Labor use per hectare	-0.02	0.00	0.02	0.04	-0.03	-0.03
	(0.79)	(0.13)	(0.39)	(0.75)	(0.83)	(0.94)
--Fertilizer use per hectare	0.12	0.14	0.13	0.14	0.16	0.17
	(3.12)***	(3.32)***	(3.20)***	(3.51)***	(2.96)***	(2.96)***
--Other production fee per hectare	0.01	0.01	0.00	0.00	0.01	0.01
	(2.31)**	(1.43)	(0.38)	(0.32)	(2.61)**	(2.91)***
Land plot characteristics						
--Dummy of loam soil	0.02	0.01	0.11	0.12	0.08	0.07
(1 yes, 0 no)	(0.56)	(0.38)	(1.81)*	(1.91)*	(1.27)	(1.07)
-- Dummy of clay soil	0.05	0.06	0.11	0.12	0.04	0.03
(1 yes, 0 no)	(1.62)	(1.67)*	(1.98)**	(2.04)**	(0.71)	(0.55)
-- Distance to home	-0.04	-0.04	0.00	0.02	-0.02	-0.03
	(1.56)	(1.61)	(0.09)	(0.39)	(0.74)	(0.80)
--Dummy of single crop	0.06	0.08	0.05	0.07	0.01	0.07
(1 yes, 0 no)	(0.95)	(1.15)	(0.44)	(0.63)	(0.11)	(0.51)
Production shock						
--Yield reduction due to disaster	-0.72	-0.75	-0.95	-0.99	-1.25	-1.24
	(3.09)***	(3.10)***	(4.29)***	(4.64)***	(4.15)***	(3.84)***
Household characteristics						
--Education years of household head	0.009	0.010	0.003	0.002	-0.017	-0.013
	(1.65)	(1.67)*	(0.42)	(0.21)	(1.79)*	(1.35)
--Age of household head	0.003	0.003	0.001	0.000	-0.007	-0.007
	(1.93)*	(1.81)*	(0.22)	(0.05)	(2.63)***	(2.46)**
--Agricultural production assets per	0.000	0.000	0.000	0.000	0.000	0.000
Capita	(0.73)	(0.87)	(0.45)	(0.25)	(0.01)	(0.09)
Dummy of irrigation district						
--Ningxia Province ID-2	0.00	0.01	0.03	0.01	-0.08	-0.07
	(0.01)	(0.18)	(0.48)	(0.14)	(0.93)	(0.76)
--Henan Province ID-1	0.24	0.26	0.29	0.25	-0.07	0.03
	(4.62)***	(4.18)***	(3.91)***	(3.11)***	(-0.50)	(0.15)
ID-2	0.17	0.16	0.17	0.12	0.13	0.30
	(2.90)***	(2.11)**	(2.10)**	(1.32)	(0.92)	(1.26)
Constant	6.12	5.87	6.74	7.27	8.14	7.05
	(14.82)***	(9.11)***	(14.27)***	(12.91)***	(13.03)***	(5.07)***
Samples	318	318	199	199	147	147
Adjusted R-square	0.33	0.27	0.24	0.23	0.32	0.32
F-statistic	10.13	7.95	4.77	4.50	4.97	5.04

Note: Numbers in brackets represents t statistic test; “*”, “**” and “***” separately represents statistic significance at 10%, 5% and 1%。

Table 9. Determinants of cropping and total income per capita by 2SLS

	Cropping income per capita				Total income per capita	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Incentive mechanism of WUA and contract						
-- Strong incentive	142	0.66				
-- Weak incentive	198	1.35				
Water utilization						
-- Water use per hectare			-0.01	-1.23	-0.05	-1.55
Irrigation condition						
-- Dummy of Groundwater irrigation (1 yes, 0 no)	5.97	0.07	-48.98	-0.54	-147.94	-0.55
-- Irrigation reliability	243	1.81*	290	1.99**	981	2.26***
-- Irrigation investment per hectare	0.01	1.76*	0.01	1.19	0	1.70*
Household characteristics						
-- Household head age	-5.3	-1.12	-5.5	-1.2	-6.57	-0.48
-- Household head education year	-9.2	-0.75	-9.49	-0.77	20.13	0.54
-- Cultivated area per household	2904	3.95***	2944.92	4.07***	3561.83	2.33***
-- Agri-production assets per capita	0.07	1.36	0.07	1.45		
-- Production assets per capita					0.08	1.25
-- Number of land plots	-1.59	-0.1	-1.18	-0.08	-92.45	-2.26***
-- Share of household labor	242	1.04	239.05	1.12	2032.66	3.14***
-- Non-agricultural labor share					14.37	4.28***
Production shock						
-- Yield reduction due to disasters	-196	-3.17***	-199.35	-3.23***		
Village characteristics						
-- Distance to the nearest road					18.12	0.25
-- Distance to the nearest bank					-53.98	-2.20***
Dummy of irrigation district						
--Ningxia Province ID-2	-77	-0.67	-264.66	-1.47	-734.11	-1.66*
--Henan Province ID-1	136	0.95	-134.38	-0.62	-1626.15	-2.90***
ID-2	268	1.86*	-55.44	-0.22	-1845.47	-2.96***
Constant	123	0.48	555.42	1.54	1191.94	1.10
Adjusted R-square	0.34		0.34		0.33	
F-statistic	9.02		9.62		7.96	
Samples	231		231		231	

Note: “*”, “**” and “***” separately represents statistic significance at 10%, 5% and 1%.

Table 10 Determinants of poverty by probit model

	Dummy of poverty			
	DF/dx	Z-statistic	DF/dx	Z-statistic
Incentive mechanism of WUA and contract				
-- Strong incentive	0.0001	0.04		
-- Weak incentive	-0.0002	-0.09		
Water utilization				
-- Water use per capita			0.000	1.58
Irrigation condition				
-- Dummy of groundwater irrigation (1 yes, 0 no)	-0.001	-1.15	-0.001	-1.04
-- Irrigation reliability	-0.004	-1.92*	-0.004	-2.27**
-- Irrigation investment per hectare	-0.000	-1.14	-0.000	-0.81
Household characteristics				
-- Household head age	-0.000	-1.02	-0.000	-1.34
-- Household head education year	-0.000	-1.12	-0.000	-1.20
-- Cultivated area per household	-0.005	-0.97	-0.005	-1.15
-- Production assets per capita	-0.000	-1.46	-0.000	-1.40
-- Number of land plots	0.000	1.64	0.000	1.80*
-- Share of household labor	0.000	0.13	0.001	0.53
-- Non-agricultural labor share	-0.011	-3.02***	-0.010	-2.99***
Village characteristics				
-- Distance to the nearest road	-0.000	-0.55	-0.000	1.78*
-- Distance to the nearest bank	0.000	1.60	0.000	1.78*
Dummy of irrigation district				
-- Ningxia Province ID-2	0.000	0.12	0.008	1.26
--Henan Province ID-1	0.013	1.39	1.430	2.13**
ID-2	0.004	0.73	0.145	1.72*
LR statistic (17 df)	50		53	
Pseudo R^2	0.41		0.43	
Samples	231		231	

Note: dF/dx is for discrete change of dummy variable from 0 to 1. "*", "**" and "***" separately represents statistic significance at 10%, 5% and 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 get an average water use per irrigation by crops in the village. According to our survey, near 80 percent of village leaders and canal managers can give a relative accurate estimation on this number which are generally consistent with local officials' estimation or their expenrimental 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 that are 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 these information are also provided by those villages that have water use estimation, we will compare these 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 mutiply it by irrigation times of crops per year in certain land plot answerred by farmers and then get annually total water use in the sample land plots of farm household. Household average water use of certain crop is the average of water use of all the plots that planting this crop.

Appendix B: Statistic Description of Major Variables

	Mean	Standard deviation	Maximum	Minimum
Dummy of WUA management	0.17	0.37	1	0
Dummy of Contract management	0.27	0.45	1	0
Dummy of incentive for WUA	0.52	0.51	1	0
Dummy of incentive for Contract management	0.71	0.46	1	0
Dummy of government intervention for WUA	0.87	0.34	1	0
Dummy of government intervention for Contract management	0.92	0.27	1	0
Household crop water use (m^3/ha)	13885	8695	44580	0
Household total income (yuan)	2342	1695	13442	15
Household cropping income (yuan)	1170	829	6853	2
Dummy of poverty	0.07	0.26	1	0
Dummy of surface water irrigation	0.83	0.38	1	0
Dummy of groundwater irrigation	0.42	0.49	1	0
Dummy of water scarcity	0.26	0.44	1	0
Irrigation reliability (%)	93	18	100	0
Irrigation investment (yuan/ha)	2853	4581	33943	0
Share of paddy area (%)	20	25	100	0
Wheat yield (kg/ha)	323	91	575	0
Maize yield (kg/ha)	397	121	675	40
Paddy yield (kg/ha)	448	106	75	720

Data source: Authors' survey