

## IRRIGATION MANAGEMENT REFORMS IN THE YELLOW RIVER BASIN: IMPLICATIONS FOR WATER SAVING AND POVERTY<sup>†</sup>

JINXIA WANG<sup>1\*,‡</sup>, JIKUN HUANG<sup>1</sup>, ZHIGANG XU<sup>1</sup>, SCOTT ROZELLE<sup>2</sup>,  
INTIZAR HUSSAIN<sup>3</sup> AND ERIC BILTONEN<sup>4</sup>

<sup>1</sup>Centre for Chinese Agricultural Policy (CCAP), Institute of Geographical Sciences and Natural Resource Research,  
Chinese Academy of Sciences, Beijing, China

<sup>2</sup>Shorenstein Asia Pacific Research Center, Freeman Spogli Institute for International Studies, Stanford University, USA

<sup>3</sup>International Network on Participatory Irrigation Management (INPIM), Islamabad, Pakistan

<sup>4</sup>International Water Management Institute (IWMI), Colombo, Sri Lanka

### ABSTRACT

The overall goal of this paper is to better understand irrigation management reforms in the Yellow River Basin, especially focusing on the effect that it will have on water use and poverty. Based on a random sample of 51 villages and 189 farmers in four large irrigation districts in Ningxia and Henan provinces, both provinces in China's Yellow River Basin, the results show that two of the major types of irrigation management institutions, water user associations and contracting, have begun to systematically replace traditional types of collective management. The impact analysis demonstrates that it is not the nominal implementation of the reforms 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 poverty alleviation, the reductions in water have little effect on higher incidences of poverty. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: irrigation management reforms; incentives; water use; poverty; China

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### RÉSUMÉ

Le but global de cet article est de mieux comprendre les réformes de gestion de l'irrigation dans le bassin du Fleuve Jaune, en se concentrant particulièrement sur leurs effets sur l'utilisation de l'eau et la pauvreté. Pour ce faire, l'article poursuit trois objectifs. Il examine d'abord l'évolution des institutions qui sont impliquées dans la réforme de gestion de l'irrigation et de sa gouvernance, particulièrement les mécanismes qui encouragent les gestionnaires de l'eau à utiliser l'eau plus efficacement. En second lieu, il cherche à identifier l'impact de la réforme de gestion de l'irrigation sur l'utilisation de l'eau par les plantes, qui est la motivation première de toute politique sur l'eau d'irrigation. En conclusion, il regarde comment les évolutions des institutions de gestion de l'irrigation affectent la pauvreté. A partir d'un échantillon aléatoire de 51 villages et de 189 paysans dans quatre grandes zones d'irrigation des provinces de Ningxia et de Henan, toutes deux situées dans le bassin du Fleuve Jaune de la Chine, les résultats montrent que deux des types principaux d'institutions de gestion de l'irrigation, les Associations et les prestataires de services, ont commencé à remplacer systématiquement les types traditionnels de gestion collective. L'analyse d'impact démontre que ce ne sont pas les aspects formels des réformes qui importent, mais plutôt la création de

\* Correspondence to: Jinxia Wang, Centre for Chinese Agricultural Policy (CCAP), Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China. E-mail: jxwang.ccap@igsnr.ac.cn

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<sup>‡</sup>Associate Professor.

nouveaux organismes de gestion qui incitent leurs responsables à économiser l'eau. En effet, quand des gestionnaires d'organismes réformés sont incités, ils économisent effectivement l'eau. Surtout, compte tenu des préoccupations de la Chine concernant la lutte contre la pauvreté, ces économies d'eau se font sans grands effets négatifs sur les plus pauvres. Copyright © 2007 John Wiley & Sons, Ltd.

MOTS CLÉS: réformes de gestion de l'irrigation; incitations; usage de l'eau; pauvreté; Chine

## INTRODUCTION

China has made great progress in poverty reduction since the late 1970s when the rural economic reform was initiated. Research has documented the rapid rise in rural incomes and reduction in poverty (Lardy, 1983; Putterman, 1992; World Bank, 2001). A number of studies have analysed the impact of institutional changes and the increased use of inputs on production growth during the reform period as well as attempted to explain the success of China's poverty alleviation efforts (Fan, 1991; Lin, 1992; Huang and Rozelle, 1996).

Despite the large investment that China has made in irrigation facilities, the most important form of investment in the agricultural sector in both rich and poor areas of the rural economy, previous studies have not been able to identify any strong impact of irrigation on the performance of any part of the rural economy. For example, Hu *et al.* (2000) find that irrigation did not contribute to the total factor productivity (TFP) growth of rice in China between 1981 and 1995. Jin *et al.* (2002) extend the work to other crops and cannot find a link between irrigation and TFP growth of any major grain crop (rice, wheat or maize). Fan *et al.* (2001) illustrate that government expenditures on irrigation have a smaller return to agriculture output when compared to other investments, such as roads, agricultural research and development and education.

Over the past two decades, many developing and developed countries have attempted to reform irrigation management by decentralizing irrigation management responsibilities in order to improve the performance of irrigation systems and the livelihood of poor farmers (World Bank, 1993; IWMI and FAO, 1995). After experiencing the rapid development of irrigation initiated during the post-World War II era, since the early 1980s governments have had to deal with a number of difficult water control issues, such as the deterioration of infrastructure, the decline of irrigated area, inefficient water use and a fall in agricultural productivity (Vermillion, 1997). Increasing financial pressure and inefficient management have been identified as two of the major sources of the problems. In response, many governments have transferred management responsibilities to local water managers. In theory, decentralizing water resource management, if structured properly, is supposed to provide the incentives needed to stabilize and improve the efficiency of irrigation and agricultural production. Unfortunately, such efforts have not always succeeded. In fact, there are a number of cases internationally, in which reform efforts have failed or generated negative influences (Easter and Hearne, 1993; Vermillion, 1997; Groenfeldt and Svendsen, 2000).

Since the early 1980s and increasingly in the late 1990s, China's policy makers have promoted irrigation management reform. 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). Difficulties in coordinating collective action, information problems and failure to get the incentives right are among the most important reasons that irrigation management reform has failed.

Even in the cases in which irrigation management reforms succeeded in making water use more efficient, few studies have documented the effect of the reforms on the poor. This is somewhat surprising since *ex-ante* there are reasons to believe that there are both positive and negative effects of such reform. On the one hand, it is easy to see how the design of irrigation management reforms themselves may have created a number of negative externalities. Since management reforms – implemented on their own – focus primarily on providing 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 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. On the other hand, unlike other public goods investment (e.g. roads or schools that might promote off-farm activities, such as migration and/or

self-employed activities), investments in irrigation will primarily affect those that are engaged in agriculture. According to work by Rozelle (1996) and others, in China when some policy or economic force ends up promoting agriculture, it usually ends up reducing inequality and helping the poor. Hence, if irrigation management reforms improve the performance of agriculture, it could be pro-poor. Despite the high stakes of the reforms, and despite the uncertainty of the effects, there is little or no empirically based work that has been conducted to understand and judge the effectiveness of irrigation management reform.

The overall goal of this paper is to better understand irrigation management reforms in the Yellow River Basin (YRB), especially focusing on the effect that they will have on water use and poverty. To pursue this goal, the paper has three objectives. First, it examines the evolution of the institutions that are involved in irrigation management reform and its governance, especially the incentive mechanisms that encourage water managers to use water more efficiently. Second, it identifies the impact of irrigation management reform on crop water use, the primary motivation of the policy. Finally, the paper explores how changes in irrigation management institutions affect poverty.

## STUDY SETTING

To increase the variation among regions (in order to facilitate our understanding in many different areas), we chose study provinces to be located in the upper and lower reaches of the YRB. Ningxia Province is located in the upper reaches of the YRB; Henan Province is in the lower reaches. Given its position in the upper reaches of the basin, access by the irrigation district officials to water resources in Ningxia is better than that in Henan. In fact, large differences in water access between the two provinces imply that there will likely be fundamental differences in how water is used by farmers and managed by the irrigation districts and villages. For example, in 2000, average per hectare agricultural water use reached 24 525 m<sup>3</sup> in Ningxia (Ministry of Water Resources, 2001). In contrast, Henan farmers used about 3810 m<sup>3</sup>, a level about six times less than that of Ningxia.

Despite the differences in water endowments, farmers in both provinces are both considered as living in some of China's poorest regions with a substantial share of the population living below the poverty line. For example, the incidence of poverty in Ningxia (18.5%) and that in Henan (17.6%) was about three times the national average (6.3%—Wang *et al.*, 2003). Because so many of the poorest of the poor in these areas are almost entirely dependent on farming, changes in irrigation management would also have implications for poverty—both positive and negative, depending on which one is to have water allocations cut or raised.

In addition, when the sample was selected, we tried to increase the variation among sample regions within each province. To do so, one irrigation district in each province was chosen in the upper reaches of province's segment of the YRB. Another was chosen in the lower reaches of the YRB within the province. Specifically, in Ningxia province we chose the Weining Irrigation District and Qingtongxia Irrigation District.<sup>1</sup> In Henan Province we chose the People's Victory Irrigation District and Liuyuankou Irrigation District.

The four sample irrigation districts have a number of similarities, but also several fundamental differences. All irrigation districts belong to a class of "large-scale" irrigation districts. The effectively irrigated area, or command area, of the irrigation districts ranges from 31 000 ha (Liuyuankou Irrigation District) to 304 000 ha (Qingtongxia Irrigation District). The two irrigation districts in Henan have been in operation for 40–50 years. In contrast, the Ningxia irrigation districts have a much longer history. In fact, several of the canals and their command area have been in operation for more than 2000 years. Despite the importance of irrigation, all four IDs are plagued by poor physical infrastructure and low efficiency of water delivery (Wang, 2002). The water delivery efficiency in these irrigation districts is for all about 40%.

Although there are unique features about each of the irrigation districts, the cropping patterns of the farmers are mostly typical of China's northern and northwestern irrigated areas. Wheat is the dominant crop, a crop that is grown almost exclusively in the winter season. In terms of cultivated area, maize is second, and is mostly a crop that is grown in rotation with wheat. Some of the farmers in our study areas also produce a number of crops that are

<sup>1</sup>The Weining Irrigation District and the Qingtongxia Irrigation District include gravity and lift irrigation subdistricts. In order to be comparable with Henan's irrigation system (mainly gravity irrigation), we only selected the gravity irrigation subdistricts in our sample.

somewhat special in north China. For example, rice is an important crop in the upper reaches of the irrigation districts in Ningxia (Weining Irrigation Districts and Qingtongxia Irrigation District) as well as certain areas in one of the irrigation districts in Henan (People's Victory Irrigation District).

After the irrigation districts were selected, we randomly chose sample villages from the census of villages in the upper, middle and lower reaches of the canals within the irrigation districts. 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 village leaders and 189 farm households.

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 users' 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 four years (1990, 1995, 2001 and 2004). In addition, enumerators also asked about how managers were compensated. When managers have rights to the earnings of the irrigation management activities (that is, to the value of the water saved by irrigation management reforms), we say that they face strong incentives (or henceforth, referred to as "*with incentives*"). If the incomes from their irrigation management 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 irrigation management reforms on water use and poverty. For example, in order to get relatively accurate measures of water use, we asked about crop water use in a number of different ways: on a per irrigation basis, the number of irrigations per crop, the number of hours per irrigation and the average depth of the water. We also systematically collected information on income and a household's poverty status. Village leaders and water managers were asked if upper-level government officials took steps to encourage the extension of reform in their villages; which affect irrigation management institutions, outcomes or both. Finally, 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.

## SHIFTING INSTITUTIONS IN IRRIGATION MANAGEMENT

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 Commune (or pre-reform) period. A *WUA* is theoretically a farmer-based, participatory organization that is set up to manage the village's irrigation water. In WUAs, a member-elected board is supposed to be assigned the control rights over the village's water. *Contracting* is a system in which the village leadership establishes a contract with an individual to manage the village's water.

### *Shifting institutions (and the governance)*

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 (Figure 1).

The share of collective management declined from 91% in 1990 to 23% in 2004. Contracting has developed more rapidly than WUAs. By 2004, 57% of villages managed their water under contracting and 19% 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).<sup>2</sup>

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

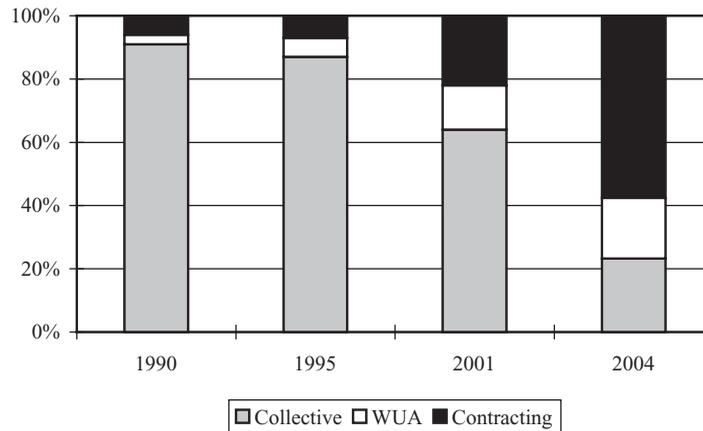


Figure 1. Evolution of irrigation management in Ningxia Province

However, the reforms are far from universal. In 2004 in Ningxia, the collective still ran 22% of the local irrigation systems in Weining Irrigation District and 24% in Qingtongxia Irrigation District. In contrast, the collective was still running nearly all of irrigation management institutions in two irrigation districts of Henan Province. Based on our field survey, although some of the differences in irrigation management among the IDs may be due to the characteristics of local villages and local irrigation management initiatives, the dramatic differences between the nature of water management in Ningxia and Henan provinces suggest that upper-level government policy may be playing an important role. In 2000, in order to promote irrigation management reforms, Ningxia provincial water officials issued several documents that encouraged localities to proceed with irrigation management reform. Regional water officials and irrigation district managers made a considerable effort to promote irrigation 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) reforms.

While the shift in China's irrigation management institutions demonstrates 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. An examination of the way the managers are compensated perhaps shows the greatest difference between theory and practice. Prior to the farming year, irrigation district 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 used as the basis to create the farmer's water fee. Therefore, this form of volumetric water fee provides the farmer with no incentives to save water since he/she pays a fixed fee for each hectare of land.

Although there may be no incentives for farmers to save water, water managers in some—but not all—communities do face incentives. In implementing irrigation management reforms, irrigation district 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 “incentive part” of their reform packages, regardless of whether they opted for WUAs or contracting (Figure 2). For example, in 2001, on average, leaders in only 41% of villages that reformed their water management institutions offered WUA and contracting managers incentives that could be expected to induce managers to exert effort to save water in order to earn an excess profit. In the rest of the reform villages, although there was a nominal shift in the institution type (that is, leaders claimed that they were implementing WUAs or contracting), in fact, from an incentive point of view, the WUA and contracting managers faced no incentives. In these villages, water managers are like village

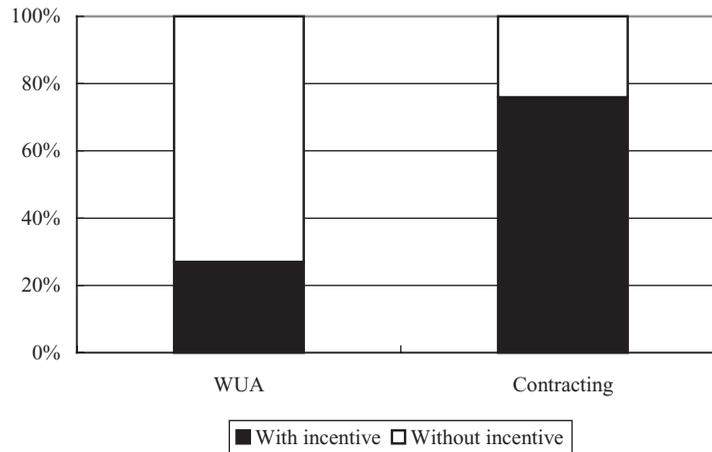


Figure 2. Incentives and institutional types in Ningxia Province

leaders in a collectively managed system in that they do not have a financial incentive to save water. Hence, to the extent that the incentives are the most important part of the reform, the differences across time and space mean that it would not be surprising if in some – but not all – villages WUAs and contracting were more effective at saving water than in other villages.

## IRRIGATION MANAGEMENT INSTITUTIONS AND WATER USE

Although the major objective of irrigation management reforms 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 when compared to those areas still under collective management is lower in some areas, but higher in others (Table I). For example, in the Qingtongxia Irrigation District in Ningxia, the water use per hectare in areas that have reformed water management (that is, villages with 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 irrigation districts, water use per hectare is higher in those villages that have shifted to WUAs or contracting (rows 1 to 3). In other words, when examining *nominally* the way that water management institutions are reformed in village, there is no explicit link between reform and water savings.

While the effectiveness of changing nominally from collective to non-collective management in terms of water saving is not clear, our data do show the importance of incentives (Table II). After reform, when managers face

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

	Crop water use (m <sup>3</sup> ha)
Weining Irrigation District	
Collective	21 294
WUA	23 460
Contracting	30 969
Qingtongxia Irrigation District	
Collective	16 549
WUA	15 483
Contracting	11 351

Data source: Authors' survey.

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

	Crop water use (m <sup>3</sup> ha)		
	Non-collective with incentives	Non-collective without incentives	Collective
Whole samples	12 729	20 598	14 003
By irrigation districts:			
Weining Irrigation District	25 055	26 583	21 924
Qingtongxia Irrigation District	11 188	14 711	16 549
By crops:			
Wheat	5 619	7 416	7 489
Maize	7 004	7 704	7 266
Rice	31 307	31 688	36 949

Data source: Author's survey.

Note: Non-collective institutions include WUA and contracting.

incentives to earn profits by saving water, water use per hectare falls by nearly 10% when compared to collectively managed systems across our Ningxia sample. In contrast, when leaders implement irrigation management reform without providing incentives, water use rises. When examining the individual irrigation districts in Ningxia, it was also found that in both cases water use either falls more or does not rise as much, when incentives are provided during reform than when they are not. In Qingtongxia Irrigation District, for example, water use falls in both non-collective systems with and without incentives, but it falls further for those with incentives. In Weining Irrigation District, although water use in the both non-collective systems rises, it rises by less for those with incentives. We also find the same patterns occur when examining individual crops.

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

#### *Analysis using Multivariate Empirical Models (MEMs)*

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

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

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 irrigation 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 each village's production environment and cropping structure. For example, we include a number of variables to control for the production environment, such as the source of water (either surface or ground), the degree of water scarcity and the level of irrigation investment per hectare. 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 irrigation district that serves the household. The symbols  $\alpha$ ,  $\beta$ , and  $\gamma$  are parameters to be estimated and  $\varepsilon_{jk}$  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.

Table III. Determinants of crop water use at the household level

	Water use per hectare			
	OLS	OLS	2SLS	2SLS
Water management institution				
Share of WUA	-1 311.0 (0.70)		-1 919.9 (1.00)	
Share of contracting	-703.7 (0.49)		-2 468.6 (1.34)	
Share of non-collective with incentives <sup>a</sup>		-2 843.8 (1.72)*		-6 355.7 (1.99)**
Share of non-collective without incentives <sup>a</sup>		275.2 (0.18)		1 107.6 (0.43)
Production environment				
Share of village surface water irrigation	2 390.7 (0.99)	2 141.8 (0.90)	2 560.5 (1.08)	2 494.7 (1.06)
Dummy of village water scarcity (1 yes 0 no)	-3 574.1 (3.13)***	-3 811.8 (3.34)***	-3 463.5 (3.03)***	-3 533.9 (3.13)***
Village irrigation investment per hectare	-0.1 (1.01)	-0.1 (0.52)	-0.1 (1.11)	0.0 (0.23)
Cropping structure				
Share of village rice area in 1995	10 592.2 (4.18)***	10 430.4 (4.17)***	10 655.0 (4.23)***	10 437.3 (4.18)***
Household characteristics				
Age of household head	519.4 (1.17)	447.4 (1.02)	551.8 (1.25)	517.2 (1.18)
Squared age of household head	-6.3 (1.28)	-5.6 (1.15)	-6.7 (1.37)	-6.3 (1.29)
Education of household head	-81.9 (0.50)	-78.7 (0.48)	-79.2 (0.48)	-58.6 (0.36)
Arable land per hectare of household	-10 486.7 (2.23)**	-7 920.4 (1.64)	-8 964.5 (1.89)*	-6 326.9 (1.26)
Constant	14 261.4 (1.43)	15 130.4 (1.53)	13 821.5 (1.39)	12 514.5 (1.27)
Observations	189	189	189	189
Adjusted $R^2$	0.44	0.45	0.45	0.45

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

Non-collective institutions include WUA and contracting.

\*Significant at 10%; \*\*Significant at 5%; \*\*\*Significant at 1%.

Our empirical estimation performs well for our water use model (Table III). 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 (row 8). We also find that those villages that face more severe water shortages use less water per hectare (row 6).

More importantly, 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 III, column 1). Although, the signs on the coefficients of the WUA and contracting variables are negative (relative to the base-collectively managed irrigation management), the standard errors are large (rows 1 and 2). In other words, according to the multivariate analysis, water use is not affected by merely implementing a management reform policy (rows 1 and 2).

But while nominally reforming water management does not affect water use, the results show that when incentives are provided, water use can be reduced (Table III, column 2, rows 3 and 4). Econometric results show that the coefficient on the incentive indicator variable is negative and significant (at the 10% level), when compared to collective management, the omitted institutional type (row 3). In other words, without regard to the form of the irrigation management institution, if managers face positive incentives, water use per hectare can be reduced by nearly 3000 m<sup>3</sup>, about 20% of their typical water use.

Although interesting, it is possible that the estimated parameter is biased since water use per hectare and irrigation 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 because they are concerned about the pending water crisis. In such a situation, the coefficient on the irrigation 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 irrigation 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 irrigation management institution variable,  $M_k$ :

$$M_k = \alpha + \beta IV_k + \gamma Z_k + \varepsilon_k \quad (2)$$

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 of 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 Equation (2) that we use to address the endogeneity problem is a variable ( $P_k$ ) that measures the effect of the decision of regional policymakers to promote irrigation 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 irrigation management reform believed that at least in the short run they were choosing villages on a fairly random basis.

When putting the predicted value of the irrigation management variable into the water use model in Equation (1), our results change little and largely support the findings from the OLS model (Table III, columns 3 and 4).<sup>3</sup> 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 rises, suggesting that the savings from providing incentives are large, and in fact even greater than indicated by the results of the model estimated with OLS. Other variables held constant, when village leaders offer managers positive incentives, water use declines more than 6000 m<sup>3</sup> ha, or about 40% of average water use (row 3, column 4).

## IRRIGATION MANAGEMENT INSTITUTIONS AND POVERTY

Irrigation management reform, at least when implemented as designed (that is, with incentives), 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 in terms of increased poverty. Our descriptive data show that poverty is worse in those villages that provide managers with incentives (Figure 3). In the villages in which leaders reformed their water management system and provided incentives to managers, poverty incidence is 11%, which is about 3–4% higher than those villages either reformed but with no incentives for managers or still managed by a collective. It

<sup>3</sup>The assumptions of the model estimated by Ordinary Least Squares (OLS) are standard in the economics literature. It is a model used when an analyst wants to understand the net contribution of a factor (an explanatory factor) on a variable of interest (the dependent variable). OLS can be used to compute the best, linear, unbiased estimate of the relationship between the explanatory and dependent variable if the expected correlation between the explanatory variable and the error term (the unexplained part of the variability of the dependent variable) is zero. If this condition is violated (for example, if there is an omitted variable that is correlated with both the explanatory and dependent variables), an alternative estimating approach is needed, for example an Instrumental Variables approach. In our analysis we adopt both approaches in order to assess the robustness of our findings to the choice of estimating approach.

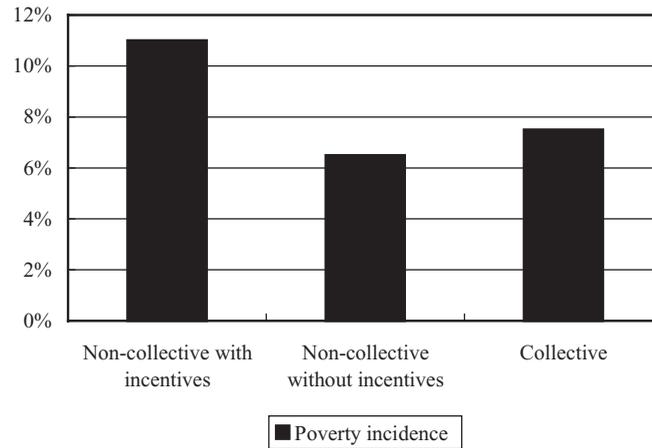


Figure 3. Incentives and poverty incidence in Ningxia and Henan provinces

seems that water management reform will worsen the poverty status of farmers. However, since other socio-economic factors also influence poverty, it is necessary to use econometric analysis to isolate the effects of reform on poverty.

#### *Analysis using Multivariate Empirical Models (MEMs)*

In addition to irrigation management reform, other socio-economic factors also influence agricultural production, income and poverty. In order to answer the question of whether irrigation management reform affects outcomes, it is necessary to control for these other factors. To do so, we specify the link between poverty and its determinants as:

$$y_{jk} = \alpha + M_{jk}\beta + Z_{jk}\gamma + D_{jk} + \varepsilon_{jk} \quad (3)$$

where  $y_{jk}$  represents a dummy variable of poverty status for household  $j$ , and the other variables, including  $M_{jk}$ , our interested variable (a measure of incentives) are the same as in Equation (1).

The model specified on poverty performs well and produces robust results that largely confirm our *a priori* expectations (Table IV). Coefficients of our control variables in the model were of expected sign and statistically significant. For example, the model shows that production shocks adversely affect the household's poverty status (row 13). Higher levels of plot fragmentation also negatively affect poverty (row 12).

Importantly, our research results demonstrate that irrigation management reform has no apparent impact on the poverty status of the sample farmers (Table IV). When we use either the OLS or 2SLS estimating approaches, the coefficients on the incentive variables in the poverty models are not statistically significant. Since we measure poverty status as “under the poverty line or not”, our results can be interpreted as saying that there is no effect of a village's decision to provide water managers with incentives on the poverty status of the sample households. In other words, our results imply that water management reform (when accompanied with incentives), and the water savings that it produces, does not come at a cost of increased poverty.

## CONCLUSIONS

In this paper, we have sought to understand the evolution of China's surface irrigation management systems and its effect on water use and poverty. Research results show that since 1990, and especially after 1995, collective management has been replaced by non-collective water management institutions – in the form of either WUAs or contracting systems. In some regions, non-collective management forms even have become the dominant pattern.

Table IV. Determinants of poverty

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

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

<sup>a</sup>Non-collective institutions include WUA and contracting.

\*Significant at 10%; \*\*Significant at 5%; \*significant at 1%.

Unfortunately, just implementing reforms does not guarantee success. The results suggest that nominally reforming water management does not lead to water savings.

The results, however, do show that the design of water management reforms is important and can lead to water saving without adverse effects on poverty. Our results show that if managers are provided with positive incentives to earn money by saving water, they can improve irrigation management, and water delivered to farmers can be significantly reduced. More importantly, our analysis finds that even though irrigation managers have incentives to reduce water deliveries, it can be done (at least in the early stages of reform in our study area) without producing negative impacts on poverty. Although these results need to be further explored for possible long-term impacts,

concern about the potential negative impacts of irrigation management reforms, at least in the short term, seems to be unwarranted.

As a consequence, we propose that the government should continue to support the irrigation management reform process. However, different from the initial stage—when villages were pushed to implement reforms without consideration of their design, more emphasis should be put on the effective implementation of the reforms. Moreover, although we have not found a negative impact on farmers in the short term, in the longer term the government still needs to focus on this issue and adopt measures to promote the healthy reform of irrigation management. Since reform can lead to water savings, the amount of water savings and how to efficiently reallocate the saved water to other water-short regions are two important issues that need to be further explored by researchers and policy makers.

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