Policy Supports, Economic Incentives and the Adoption of Agricultural Water-saving Technology in China

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ABSTRACT

Water scarcity is increasing in many parts of China due to increased demand from agriculture and other water uses, and to variations in supply due to climate change. Chinese agriculture uses over 60% of the total available water with low irrigation efficiency. In this context, the Chinese government has promoted the adoption of irrigation water-saving technology using a range of policies, but their impacts are not known. Using data collected at field, household and village scales, the determinants of adoption of household-based and community-based modernization of water-saving technologies are investigated using Logit and Tobit models, with particular reference to policy interventions.

It is shown that in spite of growing water scarcity, overall adoption of water-saving technology is low, and remains low in the absence of policy driven incentives and support, such as subsidies and promotional activities. The estimated results of the models show that they all have a good performance. The availability of subsidies has a positive and significant impact on the extent and intensity of adoption of both types of modern water-saving technologies. The existence of extension service activities shows also a significant impact on most of the cases, but its magnitude is lower than the effect of subsidies. Nevertheless, extension service activities are necessary. Finally, a proxy variable for the water price presents a positive and significant impact on the extent of adoption of household-based water-saving technology.

SUBJECT DESCRIPTORS (JEL Codes):

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1. Introduction

Increasing industrial and urban demands for water and climate change are intensifying the pressure on agricultural water use in China. Water is scarce in China: the annual per capita water availability is only approximately one-quarter of the world average (MWR, 2010). With increasing water demand from the industrial and domestic sectors, the share of water used in agriculture has declined from 97% in 1949 to 62% in 2010 (Wang et al., 2005, MWR, 2010). In addition, there is concern about future water deficits in irrigated agricultural production areas due to climate change; such deficits are projected to cause an estimated 7 to 14% drop in rice production that would threaten food security (Xiong et al., 2010). Furthermore, agricultural production in China is concentrated in areas that are increasingly prone to water shortages (FAO, 2011; Wu et al., 2010; Wu and Zhao, 2010). Some areas have also experienced environmental problems associated with water pollution and sea-water intrusion, thus limiting the availability of water for agricultural use (Mei and Dregne, 2001).

The challenges China faces in terms of water availability in the agricultural sector are exacerbated by the sector's low irrigation efficiency (Cheng et al., 2009; Yang et al., 2003). In 2010, irrigation efficiency in China was estimated to be 48% on average; this rate is lower than that of some developed countries such as Israel (75%) (Wang et al., 2010). Such low agricultural irrigation efficiency is one of the major drivers of increasing water scarcity in China. Improved irrigation efficiency is needed to support any proposed expansion of irrigation; however, an improvement is even necessary to maintain the use of existing irrigation capacity in the face of increasing demand for water from other sectors (Cheng and Hu, 2011; Zhang et al., 2005). Water-saving technology can make a substantial difference in efficiency and contribute to the adaptation of the agricultural sector to climate change in China (Zou et al., 2012; Zhao et al., 2010; Erenstein et al., 2008; Belder, 2004). However, the adoption rate of agricultural water-saving technology is low in China (Blanke et al., 2007).

To increase irrigation efficiency, promoting water-saving technology has been emphasized by policy makers in China (Cheng et al., 2009). The Chinese Government stated that the promotion of water-saving technology is one of the priorities in its water conservancy reforms (CPC, 2010; USDA, 2011a). Issued in March 2011, the rural and agricultural parts of the 12th Chinese 5 Year Plan highlight the importance of efficiency and technological innovation (CPC, 2011a; USDA, 2011b). In addition, the Chinese Government has announced expenditures of four trillion RMB (over US$600 billion) on water conservation over the next 10 years (CPC, 2011b) and a specific investment of US$6.03 billion to support the adoption of water-saving technology on 2.53 million hectares (Xinhua, 2012). There is clearly a strong policy commitment to diffusing water-saving technology, but the likely impact of these interventions on the adoption of water-saving technology remains largely unknown.

The existing literature tells us that policy support is an important factor in farmers' decisions whether to adopt water-saving technology. Policies promoting adoption of water-saving technology often aim to overcome farmers' economic and technical constraints. To overcome economic constraints, direct provision of subsidies is proven to be an important policy measure in increasing the adoption rate of agricultural water-saving technology, especially when the prevailing adoption rates are low (Feder and Umali, 1993; Tiwari and Dinar, 2000). Based on an econometric analysis, Liu et al. (2008) found a significant positive relationship between subsidies and adoption of some types of water-saving technology in rural China. In terms of technical constraints, providing knowledge and technical advice through extension service activities are effective ways to increase the adoption rate of agricultural water-saving technology (Dong, 2008; Feder and Umali, 1993; Ommani et al., 2009).

In addition to policy support, setting rational economic incentives for farmers is another important factor that influences farmers' technology adoption behavior. International experiences indicate that water price is a significant determinant of adoption of water-saving technology in the agricultural sector (Dinar and Yaron, 1992; Negri and Brooks, 1990; Zilberman and Caswell, 1985). Although Blanke et al. (2007) do not conduct a quantitative analysis, they argue that reforming water pricing in China will promote the adoption of agricultural water-saving technology. However, most research concurs that the 'price' of water in terms of actual water charges is low in China's agricultural sector, which constrains its potential role in promoting the use of water-saving technology (Finlayson et al., 2008; Huang et al., 2010).

To design more effective policies to foster the adoption of water-saving technology in China, it is essential to answer the following questions: What is the current extent of adoption of water-saving technology in rural China? Have interventions such as subsidy and extension policies played a significant role in promoting the adoption of water-saving technology? Could economic incentives established through a water pricing policy play an important role on increasing the adoption rate of water-saving technology? Despite a relatively rich international literature quantitatively analyzing the determinants of agricultural water-saving technology (Webb et al., 2005; Zilberman and Caswell, 1985; Dinar and Yaron, 1992), such studies focused on China are very few. We only found a few quantitative analyses that explore the factors influencing the adoption of agricultural water-saving technology in China, such as those by Liu et al. (2008) and Zhou et al. (2008). More importantly, no study has assessed the effectiveness of economic incentives in promoting the adoption of water-saving technology in rural China. The overall goal of this paper is to understand the effect of policy supports and economic incentives on the adoption of agricultural water-saving technology in China. With this goal in mind, the following objectives have been specified. First, we will examine the extent of adoption of water-saving technology at households and village levels. Second, we will quantitatively identify the policy drivers that have been most important in promoting the take up of water-saving technology. Third, we will explore the influence of economic incentives (in terms of charges for irrigation water) on the adoption of agricultural water-saving technology.

The paper is organized as follows. The next section explains data sources. Section 3 presents current levels of adoption of water-saving technology. Section 4 demonstrates the association between policy interventions and the adoption of water-saving technology. Section 5 describes the use of econometric models to explain water-saving technology take up. Section 6 discusses the results and develops policy recommendations.

2. Data

The data used in this study are collected from one large-scale field survey conducted in seven provinces in China, which allow for regional variation in geophysical conditions and levels of socioeconomic development. These seven provinces include Beijing and Hebei in the Haihe River Basin (RB), Jilin in the Songliao RB, Anhui in the Huaihe RB, Sichuan in the Yangtze RB, Yunnan in the Southwest RB and Zhejiang in the Southeast RB (Figure 1). When selecting provinces for the field survey, we have accounted for the differences in climate and water resources between Northern and Southern regions; in addition, the pattern of diverse economic development has been considered. For example, the survey samples cover three river basins (Songliao, Haihe and Huaihe RBs) characterized by less precipitation, while the other three river basins (the Yangtze, Southwest and Southeast RBs) have more abundant precipitation and water resources. These regions also represent high (Zhejiang Province), middle (Jilin and Hebei Provinces) and low (Anhui, Sichuan and Yunnan Provinces) levels of economic development (NBSC, 2010).

Stratified random sampling was used in each province to select study areas. First, we divided all counties in each province into three quantiles by the per capita annual net income of rural residents in 2009. In each quantile, we randomly selected one county to be surveyed. After the counties were chosen, we randomly selected two townships in each county and three villages in each township for field surveys. In each village, we randomly selected 10 households with which to conduct the field survey. Therefore, the survey sample included a total of 20 counties, 40 townships, 123 villages and 1269 households.

In each village, we conducted two surveys, the household and the village surveys. The household survey questionnaire included 7 sections and the village survey questionnaire included 14 sections. The household survey was conducted through face-to-face interviews. In the household survey, we interviewed heads of farm households. The information regarding adoption of water-saving technology was collected in two ways. First, we asked each household if they were using any type of water-saving technology in any of the fields of their crop-sown areas. Based on this variable, we can measure the extent of adoption of water-saving technologies at the household level; that is, we can calculate the percentage of households that have adopted water-saving technology. Second, at the field level, we measure the proportion of the total crop-sown area to which the household actually applies the water-saving technologies. That is, in addition to the extent of adoption of water-saving technology, we also can measure the intensity of adoption of water-saving technology.

In addition to information about the adoption of water-saving technology, we also collected information about the expenditure on water and the basic characteristics of households and fields in the household questionnaires. Expenditure on water was measured as the amount of annual per-area water fees. The characteristics of households included the gender, age and the years of education of the head of household, the proportion of non-farm employment in household, household assets and net cropping income. The field characteristics included crop-sown area, soil type, soil quality, salinity, the exclusive use of groundwater, the characteristics of the terrain and the distance from the households to the field. The descriptive statistics of the main information collected from the household survey are summarized in Table 1.

The village survey also consisted of face-to-face interviews. The main respondents were village leaders such as the village party secretary, the village head and village accountants. The village questionnaire covered several issues related to policy support, village characteristics and water scarcity. Information collected about policy support comprised the availability of subsidies for water-saving technology devices and materials, and the existence of extension service activities. These extension activities may have included activities carried on by technologists, meetings, issuing of advisory documents and operation of experimental areas. The village characteristics include the proportion of irrigated area of the village and the distance to town government. Water scarcity information included whether there was a lack of groundwater during last 5 years. In the village survey, we also collected information about water-saving technology, asking village leaders to estimate adoption rates and for which crops were they used. Table 1 also provides the descriptive statistics for major information collected from the village. Finally, we obtained the average annual precipitation data for each county from the Chinese National Meteorological Information Center.

3. Adoption of Water-saving Technology

For analytical convenience, Blanke (et al., 2007) have divided water-saving technologies into three groups: traditional, household-based and community-based. Traditional water-saving technology includes border irrigation, furrow irrigation and field leveling. These technologies are characterized by relatively low fixed costs and are divisible in the sense that one farm household can adopt the practice independently of its neighbors. Traditional water-saving technologies are already widely adopted in China; they were used prior to the period of agricultural reform of the late 1970s and early 1980s. For example, even in 1949, farmers in 55% of northern China villages were already leveling their land (Blanke et al., 2007). During the reform period, the adoption of traditional technologies grew slowly, in part due to the relatively high prevailing adoption rate. More importantly, when policy makers and scholars in China mention the adoption of water-saving technologies, they mainly emphasize the adoption of household-based and community-based water-saving technology. Unlike traditional water-saving technology, these two categories of water-saving technologies have begun to be adopted mainly since the 1980s. Given this observation, we refer to them as modern water-saving technology. In our paper, we focus our discussion on the adoption of modern water-saving technologies.

As modern water-saving technology, household-based and community-based water-saving technologies each have unique characteristics. Household-based water-saving technologies includes intermittent irrigation, surface pipes, plastic-film mulching, reduced or no tillage, retaining stubble, incorporation of crop residue and use of drought-resistant crop varieties. Household-based water-saving technologies can be adopted separately by each household and have low fixed costs. Community-based water-saving technologies include sprinklers, drip irrigation, underground pipes and lined canals. These technologies are not typically adopted by single households; they normally require collective organization by farmer groups or village committees. In contrast to other agricultural water-saving technologies, community-based water-saving technologies have high fixed costs. The adoption of sprinklers, drip irrigation and underground pipes is more recent (1990s) than the adoption of household-based technology, but lined canals were used earlier (Blanke et al., 2007).

In the following discussion, we will examine the adoption of water-saving technology in two dimensions: the extent of adoption and intensity. The extent of adoption measures how spatially pervasive the water-saving technology has become. To measure the extent of adoption, we apply the information collected both at the village and household levels. At the village level, we intend to reveal the percentage of villages that are adopting the water-saving technology. By our definition, if even a single household in the village adopts the water-saving technology, the village is considered to have adopted the technology. Similarly, even if a household uses a technology on only one field, the household is considered as having adopted the water-saving technology. The extent of adoption at the household level is measured by the percentage of households adopting the water-saving technology. Finally, we use the percentage of crop sown areas adopting the water-saving technology to measure the adoption intensity.

Our data indicate that almost all villages in China have adopted the household-based water-saving technology. In the case of community-based water-saving technology, only about half of villages adopted it. For example, 99% of sampled villages adopted household-based water-saving technology in 2010 (Table 2, column 1). When we check the adoption rate by province, we found that in addition to Jilin Province (94% of villages), in other provinces (such as Beijing, Sichuan, Zhejiang, Anhui, Hebei and Yunan Provinces), 100% of their villages adopted the household-based water-saving technology. It implies that household-based water-saving technology has become a pervasive practice for famers to increase irrigation efficiency of agricultural activities. However, only 47% of villages have adopted community-based water-saving technology (column 2). In addition, adoption of community-based water-saving technology varies among regions. In Beijing Province, 100% of villages have adopted community-based water-saving technology; this is the same figure as for the household-based technology. In Yunnan, Sichuan and Zhejiang Provinces, more than half of the villages have adopted community-based water-saving technology. In the other 3 provinces, the adoption rate of community-based water-saving technology is low. Adoption in Jilin Province is particularly low: only 11% of villages have adopted community-based water-saving technology. Because the adoption of community-based water-saving technology generally needs the support of the government, the adoption rate of community-based water-saving technology is also likely to reflect the policy support associated with various regions.

Consistent with the village level data, the household-level adoption rate of household-based water-saving technology is much higher than that of community-based water-saving technology. For example, 73% of all households reported that they have adopted some type of household-based water-saving technology in 2010 (Table 3, column 1). The adoption rate of household-based water-saving technology ranges from 45% in Zhejiang Province to 98% in Beijing Province. Turning to community-based water-saving technology, we find that only 17% of households have adopted this category of water-saving technology (column 2). Only 73% of Beijing's households are using community-based water-saving technology in their fields; in other provinces, the adoption rate is less than 20% of households, which is much lower.

Despite the relatively high adoption rate of household-based water-saving technology at the village and household level, its actual adoption on crop-sown areas is not high: less than half of crop-sown areas are utilizing this technology. The adoption rate for community-based water-saving technology is even lower. For example, our data reveals that in the full sample, household-based water-saving technology is used on only 32% of crop-sown areas (Table 4, column 1). The highest adoption rates are still found in Beijing and Yunnan, covering 92% and 71% of crop-sown areas, respectively. This finding implies that in Beijing Province, the adoption of household-based water-saving technology is on both the extensive and intensive margins. The adoption of household-based water-saving technology ranged between 30% and 40% in Jilin, Sichuan, and Hebei Provinces. In the other two provinces (Anhui and Zhejiang Provinces), adoption intensity for household-based water-saving technology is not high. This observation is particularly true of Zhejiang Province (only 5% of crop-sown areas). It is also not surprising to find that the adoption intensity of community-based water-saving technology is low; in six provinces (Jilin, Zhejiang, Anhui, Hebei, Yunnan and Sichuan Provinces), intensity is only between 1% and 10% (Column 2). Our data are consistent with the findings of other researchers (such as Blanke et al., 2007; Liu et al., 2008). All of these prior studies found that the intensity of adoption of water-saving technologies is very limited.

4. Policy Supports, Economic Incentives and the Adoption of Agricultural Water-saving Technology in China

Consistent with other studies (Dinar and Yaron, 1992; Ommani et al., 2009), descriptive statistical analyses show the possibility of a positive relationship between the adoption of water-saving technology and policies encouraging it. In our analysis, we use two variables to represent policy support: a subsidy for investing in water-saving technology and extension services that assist farmers in becoming familiar with the application of water-saving technology. Based on our field survey, we found that 14% of households have access to the subsidy policy. More importantly, when the subsidy policy is available for farmers, they are more likely to adopt both household-based and community-based water-saving technology. For example, if the subsidy is available, 93% of households make the decision to adopt household-based water-saving technology; the adoption rate is only 69% if the subsidy is not available (Table 5, column 1). Similarly, if farmers can obtain the subsidy when they invest in water-saving technology, their adoption rate for community-based water-saving technology (41%) is also considerably higher than without the subsidy (13%).

When the subsidy policy is available, the percentage of crop-sown areas to which water-saving technology is applied is higher. Specifically, in households where the subsidy is available, the average intensity of adoption of household-based water-saving technology is 69% (Table 5, column 3), while the average intensity of adoption is lower (29%) in those households where the subsidy policy is not available. In the case of community-based water-saving technology, the availability of subsidies makes an even larger difference. If the subsidy is available, the average intensity of adoption of community-based water-saving technology is 19% (Table 5, column 4), while the figure is much lower (3%) if the subsidy policy is not available. This larger difference most likely arises because community-based water-saving technology has higher fixed costs; thus, the subsidy policy plays a fundamental role in adoption.

Our data also show that when extension services are available, the likelihood that farmers will adopt water-saving technology is higher. According to our field survey, 59% of households had access to support activities from extension services. When extension services are available, 80% of households adopt household-based water-saving technologies, while the rate of adoption is only 63% if these services are not available (Table 5, column 1). Similarly, the availability of extension services is associated with a higher adoption rate of community-based water-saving technologies (23% versus 9%, column 2). Likewise, the provision of extension services also appears to increase the adoption intensity of water-saving technology. If the extension service activities are implemented, the adoption rate of household-based water-saving technology increases from 25% to 37% (column 3), and the adoption rate of community-based water-saving technology increases from 2% to 5% (Column 4). Although the availability of extension services seems to have an impact on the intensity of adoption, the differences of values in Table 5 imply that the availability of subsidies may have a larger impact on the adoption of water-saving technology.

Payment for water is an economic incentive that can lead to water conservation through the adoption of water-saving technologies (Tiwari and Dinar, 2000). Among the surveyed households that irrigate, almost all farmers that use groundwater exclusively pay for water; only roughly half of the exclusive surface water users pay for it. Surface water users pay less often for water because they usually have more options from which to obtain water. Some of these options are free, such as using water directly from rivers, water cellars, ponds, small streams or springs. In accordance with previous findings in the literature (Negri and Brooks, 1990; Zilberman and Caswell, 1985), our descriptive statistical analyses suggest the existence of a positive relationship between payment for water and the adoption of modern water-saving technology. Payment for water is reflected by values of the variable ratio of water fee to net cropping income of household (WFCI) bigger than 0. Among the surveyed households, we found that values of WFCI bigger than 0 make a notable positive difference in terms of adoption of household-based and community-based water-saving technology. For example, Figure 2 displays that, in households that have values of WFCI bigger than 0, the adoption rate of household-based water-saving technology is approximately 14% higher than it is among those with a WFCI value of 0. There is also an upward trend as the value of WFCI increases. Similarly, Figure 3 displays a similar increase in the adoption of community-based water-saving technology in those households that have values of WFCI higher than 0. In figures 2 and 3, for farmers paying some amount for water, the differences among the following levels of WFCI are smaller (less than 10%). One reason for this is that water is priced per irrigated area as opposed to volumetrically; hence, once farmers start to pay for water, they have little incentive to save water by adopting water-saving technology.

Further exploring the relationship between payment for water and the percentage of crop-sown areas adopting water-saving technology, we find that households that pay for water(i.e., those with values of WFCI greater than 0), the intensity of adoption has an initial tendency to rise. For instance, the value of intensity of adoption of household-based water-saving technology in those households that pay a low percentage of their cropping income for water (WFCI from 0 to 0.05%) is approximately 25% higher than in those households that do not pay for water at all (WFCI equal to 0) (Figure 4). Similarly, the intensity of adoption of community-based water-saving technology is initially higher in those households with values of WFCI higher than 0 (Figure 5). It is noteworthy that beyond low positive levels of WFCI, the intensity of adoption of both household-based and community-based water-saving technology (Figures 4 and 5) begin to decrease. A possible explanation is that higher payments for water could diminish the options for investing in modern water-saving technologies in this low-income context.

5. Econometric methods for modeling adoption of water-saving technologies

To determine the marginal effects of the explanatory variables on adoption of water-saving technology, a set of econometric methods have been employed to model the adoption of household and community-based water-saving technology. A logit model is used to explain the adoption decision at field level (Train, 1993). Additionally, because most households occupying more than one field do not adopt water-saving technology over their entire farming area, a Tobit model is used to explain the intensity of adoption (Feder and Umali, 1993). Recall that we define intensity as the proportion of the total crop-sown area in each household on which water-saving technology is adopted. The functional form of the logit model is presented in Equation (1) and that of the Tobit model is presented in Equation (2).

$$A_{ijk} = \alpha + \beta S_{ijk} + \gamma E_{ijk} + \delta WFCI_{ijk} + \lambda C_{ijk} + \varepsilon_{ijk} \tag{1}$$

$$I_{jk} = \alpha + \beta S_{jk} + \gamma E_{jk} + \delta WFCI_{jk} + \lambda C_{jk} + \varepsilon_{jk} \tag{2}$$

In equation (1), A_{ijk} represents adoption of water-saving technology for the *i*th field of household *j* in village *k*. A_{ijk} is a dummy variable that equals 1 when households adopt the water-saving technology in the field and 0 otherwise. Among the explanatory variables, S_{ijk}, E_{ijk} and $WFCI_{ijk}$ are the variables of interest. S_{ijk} is a qualitative dummy variable that represents the availability of subsidies to households for investing in water-saving technology; it equals 1 when the subsidy is available and 0 otherwise. Similarly, E_{ijk} is a dummy variable capturing the availability of extension service activities that equals one when the activities are available and 0 otherwise. $WFCI_{ijk}$ is the ratio of the water fee to net cropping income of the household; this variable expresses the importance of an annual per-area water fee relative to the household's economic standing.

C_{ijk} is a set of control variables included to reduce omitted variable bias. It includes variables related to village, household and field characteristics. Village variables include the proportion of irrigated area (ratio), the distance to the town government (km), the share of years characterized by groundwater shortage in the last 5 years (ratio), a dummy variable reflecting the exclusive use of groundwater (1=yes, 0=no) and precipitation (Mm). Household variables include the proportion of non-farm employment in the household (ratio), household assets (10,000 Yuan), education (years), gender (1=male, 0=female) and age (years) of the head of household. Variables related to a particular field include the distance from house to the field (km) and six dummy variables (1=yes, 0=no) regarding various characteristics of the field: loam soil, clay soil, plain terrain, high-quality field, medium-quality field and saline field. The marginal effects of the coefficients β, γ, δ and λ are the parameters to be estimated. The error term, ε_{ijk} , is assumed to be uncorrelated with the independent variables.

In Equation (2) for the Tobit model, I_{jk} represents intensity of adoption of water-saving technology for the *j*th household in village *k*, measuring the proportion of crop-sown areas adopting water-saving technology. Similar to equation (1), equation (2) also includes explanatory variables such as the availability of subsidies, the availability of extension service and WFCI. In equation (2), the variables related to village and household characteristics are the same as those in equation (1). However, in equation (2) the variables related to the characteristics of the fields of the household are not the same. Instead, they are the average distance from the house to the various fields of the households (km), and six variables reflecting the proportion of the household’s fields that exhibit a given characteristic The include the proportion of loam soil fields in the household (ratio), and five analogous variables describing the proportion of fields with the following characteristics: clay soil, plain terrain, high quality, medium quality and saline fields.

6. Results and discussion

The estimated results of the four models show that they all perform well (Table 6). The models passed the Chi-square test, and the McFadden's pseudo-R^2 values of the four models range from 0.0617 to 0.3050. These values are sufficiently high enough for regression analyses based on large-scale cross-sectional data. More importantly, many village, household and field control variables have signs that agree with our expectations and are statistically significant. For instance, in the four models, the sign of the coefficient of exclusive use of groundwater is positive and statistically significant. This outcome implies that after keeping all other factors constant, farmers using groundwater exclusively are more likely to adopt modern water-saving technologies. This result is in agreement with findings of other researchers (Yang et al., 2003; Caswell and Zilberman, 1985). The results also indicate that farmers with a higher education level are more likely to adopt water-saving technology. Furthermore, some field characteristics are also related with farmers' decision regarding adoption. For instance, adoption is positively related to plain terrain and saline condition. This relationship implies that water-saving technologies are more likely to be adopted in fields with no slope conditions and can minimize the effects of soil salinity (Castilla, 1999).

More importantly, our results demonstrate that the availability of subsidies has a positive and significant impact on adoption of both types of modern water-saving technology (Table 6,). The results show that when the subsidy policy is available to farmers, the farmers adopt water-saving technology at a significantly higher rate and with greater intensity. This is consistent with results from previous research (Bjornlund et al., 2009; Dinar and Yaron, 1992; Feder and Umali, 1993) and confirms the importance of policy factors in encouraging adoption of agricultural innovations. If a subsidy policy is adopted, the probability of adopting water-saving technology will increase by 11.7% for household-based water-saving technology and by 2% for community-based water-saving technology. While the last figure might not seem impressive, the probabilities of an increase in crop-sown areas using community-based and household-based water-saving technologies are 19.9% and 10.9%, respectively.

Consistent with earlier observations, the existence of extension service activities has a significant impact on the adoption of water-saving technology (Table 6). In all of our regressions except for the intensity model of community-based water-saving technology, the coefficient on the extension service activities variable is positive and statistically significant. This result suggests that when extension service activities are accessible to farmers, the probability that farmers adopt water-saving technology significantly increases. This is in agreement with previous findings in the literature (Dong, 2008; Feder and Umali, 1993; Ommani et al., 2009). If extension service activities are available, the possibility of adopting water-saving technology increases by 6.2% and 0.9% for household-based and community-based water-saving technologies, respectively. The lower impact of the policy on community-based water-saving technology is related to the fact that the decision to adopt community-based technology is generally made by local village leaders due to high fixed costs.

In contrast with the previous results, the proxy variable for water price, WFCI, had a limited impact on the adoption of water-saving technology. The variable WFCI only has a significant impact on the adoption of household-based water-saving technologies. This result implies that, after holding all other factors constant, when there is a payment for water the farmers are more likely to adopt these technologies. This result is consistent with previous studies from Caswell et al. (1990) and Dinar (1992). The marginal effect of the impact of WFCI on adoption of household-based water-saving technologies is 0.006, which is smaller than the marginal effects of the availability of subsidies (0.117) or the existence of extension service activities (0.062). This corroborates the findings of Green et al. (1996), indicating that other determinants are more important for adoption than water price. Moreover, the relatively low impact of WFCI on adoption of household-based water-saving technologies is likely due to low irrigation price elasticities in China (Finlayson et al. ,2008; Huang et al., 2010) and the non-volumetric payment system.

7. Concluding Remarks

In this paper, we have sought to understand the importance of policy supports and economic incentives on the adoption of agricultural water-saving technology in China. Descriptive statistical analyses show that household-based water-saving technology has become noticeable in almost every Chinese village. In contrast, only about half of Chinese villages have adopted community-based water-saving technology. Adoption levels are lower at the household level. Amongst those households adopting water-saving technologies, there are very few adopters that use modern water-saving technologies across the entirety of their crop-sown areas; this observation especially applies to community-based water-saving technology.

The results of our analysis reveal that policy support has played an important role in promoting the adoption of water-saving technology. In the future, the implementation of relevant policies needs to be strengthened further. First, subsidies are the most influential and comprehensive policy for encouraging the adoption and the intensity of adoption of both household-based and community-based water-saving technologies. However, only 10% of villages are currently eligible for such support; the subsidy policy needs to be extended to more farmers in the future. Second, the provision of extension services can make a significant contribution, even though its marginal effect is smaller than that of the subsidy. The extension programs should be continued or even extended.

Compared with policy support, the present pricing policy has played a limited role in promoting the adoption of water-saving technologies. Our results show that the payment for water and the adoption rate of household-based water-saving technology are positively and significantly related, but the marginal effect is small. To improve adoption levels, the payment for water should be extended to all farmers who irrigate. Moreover, although the marginal effect of the price signal is small, farmers do respond to some extent. Thus, the introduction of a volumetric water pricing policy is likely to encourage higher levels of adoption of water-saving technology.

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TABLES

Table 1. Descriptive statistics for major variables.

	Mean	Std. Dev.
Village level variables		
Availability of subsidies (1=Yes; 0=No)	0.1	0.31
Existence of promotional activities (1=Yes; 0=No)	0.57	0.49
Shortage of groundwater in last 5 years (Ratio)	0.07	0.23
Exclusive use of groundwater (1=Yes; 0=No)	0.07	0.26
Precipitation (mm)	1,020.6	357.44
Proportion of irrigated area of the village (Ratio)	0.57	0.36
Distance to town government (km)	6.56	5.37
Household level variables		
Adoption of modern community-based water-saving technology (1=Yes; 0=No)	0.06	0.24
Adoption of modern household-based water-saving technology (1=Yes; 0=No)	0.37	0.48
Ratio of water fee to net cropping income of household (ratio)	0.17	2.19
Amount of water fee (Yuan per ha)	936.16	52,508.66
Proportion of household's area adopting modern community-based water-saving technology (Ratio)	0.13	0.31
Proportion of household's area adopting modern household-based water-saving technology (Ratio)	0.51	0.4
Gender of household head (1=Male; 0=Female)	0.98	0.13
Age of household head (Years)	52.67	10.53
Household head's education level (Years)	6.56	3.11
Share of off-farm labor (Ratio)	0.26	0.28
Household assets (10,000 Yuan)	11.58	25.26
Field level variables		
Crop-sown area (Ha)	1.99	11.40
Loam soil (1=Yes; 0=No)	0.2	0.4
Clay soil (1=Yes; 0=No)	0.36	0.48
Plain terrain (1=Yes; 0=No)	0.54	0.5
High-quality field (1=Yes; 0=No)	0.15	0.36
Medium-quality field (1=Yes; 0=No)	0.65	0.48
Saline field (1=Yes; 0=No)	0.03	0.16
Distance from house to field (Km)	0.86	0.91

Data source: Authors' survey.

Table 2. Percentage of Chinese villages where modern water-saving technology have been adopted, 2010.

	Percentage of villages (%)	
	Household-based water-saving technology	Community-based water-saving technology
Full sample	99	47
Beijing	100	100
Jilin	94	11
Sichuan	100	50
Zhejiang	100	53
Anhui	100	17
Hebei	100	33
Yunnan	100	72

Data source: Authors' survey.

Table 3. The share of households adopting modern water-saving technology in China (adoption extent), 2010.

	Share of households adopting water-saving technology (%)	
	Household-based water-saving technology	Community-based water-saving technology
Full sample	73	17
Beijing	98	73
Jilin	55	2
Sichuan	83	16
Zhejiang	45	6
Anhui	61	3
Hebei	78	11
Yunnan	93	15

Data source: Authors' survey.

Table 4. The share of crop-sown areas adopting modern water-saving technology in China (adoption intensity), 2010.

	Share of crop-sown area adopting water-saving technology (%)	
	Household-based water-saving technology	Community-based water-saving technology
Full sample	32	4
Beijing	92	62
Jilin	29	0
Sichuan	40	5
Zhejiang	5	1
Anhui	11	0
Hebei	37	3
Yunnan	71	1

Data source: Authors' survey.

Table 5. Relationship between policy supports and adoption of modern water-saving technology

	Adoption extent		Adoption intensity	
	Share of households adopting water-saving technology (%)		Share of crop-sown areas adopting water-saving technology (%)	
	Household-based	Community-based	Household-based	Community-based
Subsidy				
Available	93	41	69	19
Not available	69	13	29	3
Extension service				
Available	80	23	37	5
Not available	63	9	25	2

Data source: Authors' survey.

Table 6. Estimates of determinants of the adoption of water-saving technology in China.

	Adoption extent: whether the households adopts water-saving technology (Logit Model)		Adoption intensity: ratio of crop sown areas adopting water-saving technology (Tobit Model)	
	Household-based	Community-based	Household-based	Community-based
Policy support variables				
Availability of subsidies (1=Yes; 0=No)	0.117***	0.020***	0.109***	0.199**
	(5.55)	(3.36)	(2.58)	(2.14)
Existence of extension service activities (1=Yes; 0=No)	0.062***	0.009***	0.068**	0.041
	(4.87)	(2.65)	(2.18)	(0.47)
Economic incentive variable				
Ratio of water fee to net cropping income of household (Ratio)	0.006*	-0.002	0.007	0.0001
	(1.91)	(0.69)	(1.19)	(0.00)
Village characteristics				
Proportion of irrigated area of the village (Ratio)	0.116***	0.052***	0.261***	0.997***
	(5.63)	(8.44)	(5.25)	(6.33)
Distance to town government (km)	-0.002**	0.0001	-0.003	0.007
	(2.01)	(0.79)	(1.00)	(0.96)
Shortage of ground water in last 5 years (Ratio)	0.088***	0.0001	0.090	0.021
	(3.27)	(0.05)	(1.60)	(0.15)
Exclusive use of groundwater (1=Yes; 0=No)	0.182***	0.096***	0.206***	0.448***
	(6.58)	(5.46)	(3.60)	(3.85)
Annual total precipitation (Mm)	-0.0001***	-0.0001***	-0.0001***	-0.001***
	(4.64)	(5.03)	(6.30)	(6.66)
Household characteristics				
Gender of household's head (1= Male; 0=Female)	-0.124***	0.0001	0.038	0.074
	(2.60)	(0.03)	(0.46)	(0.38)
Age of household's head (Years)	-0.001	-0.0001	-0.001	0.0001
	(1.57)	(0.24)	(1.01)	(0.07)
Household head's education level (Years)	0.004*	0.002***	0.004	0.033**
	(1.92)	(3.60)	(0.77)	(2.28)
Share of off-farm labor (Ratio)	-0.001	0.018***	0.015	0.112
	(0.03)	(3.55)	(0.29)	(0.82)
Household asset (10.000 Yuan)	0.0001*	0.0001***	0.0001	0.002***
	(1.67)	(3.25)	(0.57)	(2.62)
Field characteristics				
Loam soil (1=Yes; 0=No)	0.028*	0.013**		
	(1.68)	(2.51)		
Clay soil (1=Yes; 0=No)	0.005	-0.001		
	(0.35)	(0.31)		
Plain terrain (1=Yes; 0=No)	0.060***	0.022***		
	(4.71)	(5.49)		
High-quality field (1=Yes; 0=No)	0.045**	0.005		
	(2.09)	(0.86)		
Medium-quality field (1=Yes; 0=No)	0.038**	0.004		

	(2.43)	(1.06)		
Saline field (1=Yes 0=No)	0.269***	0.035***		
	(7.33)	(2.67)		
Distance from house to field (km)	-0.007	-0.002		
	(1.00)	(0.85)		
Proportion of loam soil fields in the household (ratio)			0.066	0.284**
			(1.49)	(2.41)
Proportion of clay soil fields in the household (ratio)			0.120***	0.098
			(3.31)	(1.01)
Proportion of plain terrain fields in the household (ratio)			0.083**	0.307***
			(2.23)	(2.81)
Proportion of high-quality fields in the household (ratio)			0.007	0.248
			(0.11)	(1.53)
Proportion of medium-quality fields in the household (ratio)			0.023	0.223
			(0.49)	(1.61)
Proportion of saline fields in the household (ratio)			0.139*	0.347**
			(1.71)	(2.07)
Average distance from house to fields (Km)			-0.016	0.013
			(0.79)	(0.21)
Observations	7570	7570	1191	1191
Prob > chi^2	0	0	0	0
McFadden's pseudo R square	0.0617	0.3050	0.1445	0.2845

Note: coefficients in the parenthesis are marginal effect.
Data source: Authors' survey. Absolute value of z statistics in parentheses. ***$p<0.01$, ** $p<0.05$, * $p<0.1$

FIGURES

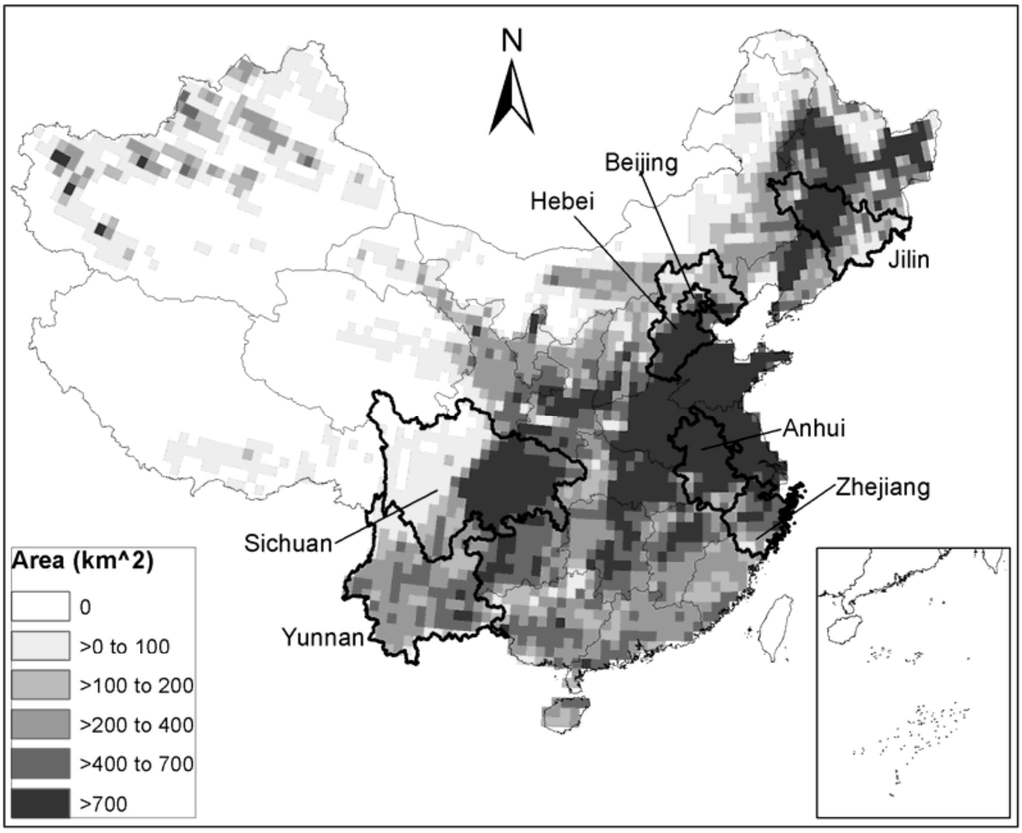

Figure 1. Map of China illustrating the surveyed provinces in bold over pixels showing density of square kilometers of total sown area of rice, wheat, maize and soy in 2000. Source: Authors, using data from Qiu et al. (2003).

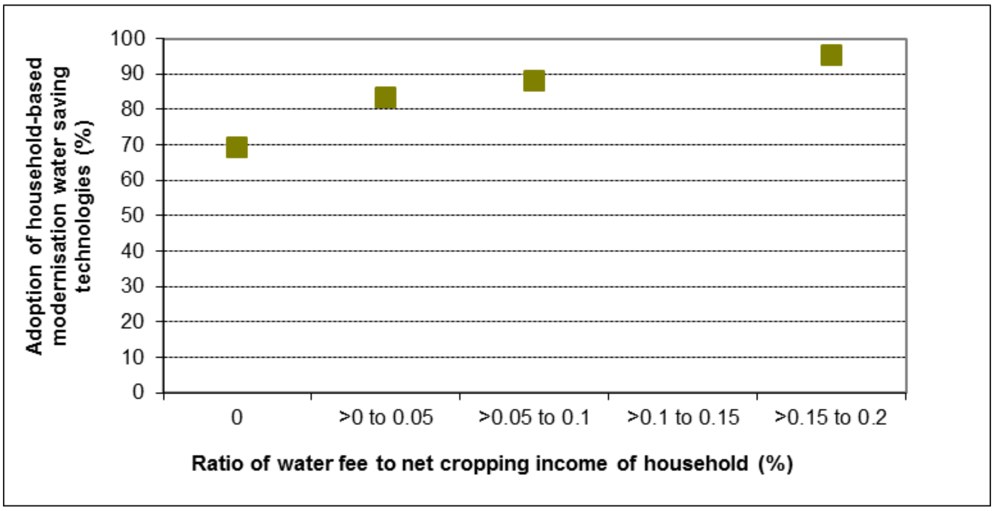

Figure 2. Relation between the ratio of water fee to net cropping income of household and percentages of households adopting household-based modern water-saving technology in China, 2010. Data source: Authors' survey.

Note: The relation is shown only when the expected frequency of the Pearson chi2 test is 5 or greater and statistically significant (p<0.1).

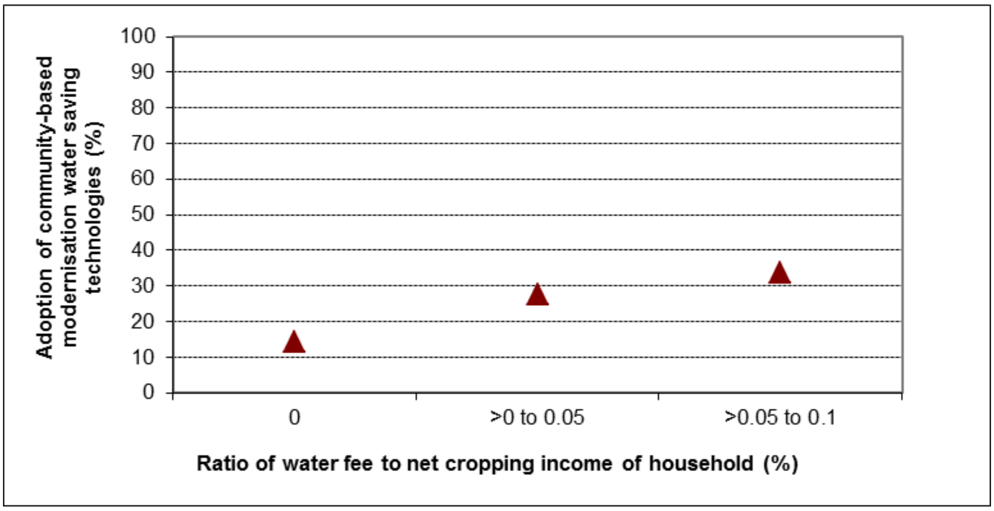

Figure 3. Relation between the ratio of water fee to net cropping income of household and percentages of households adopting community-based modern water-saving technology in China, 2010. Data source: Authors' survey.

Note: The relation is shown only when the expected frequency of the Pearson chi2 test is 5 or greater and statistically significant (p<0.1).

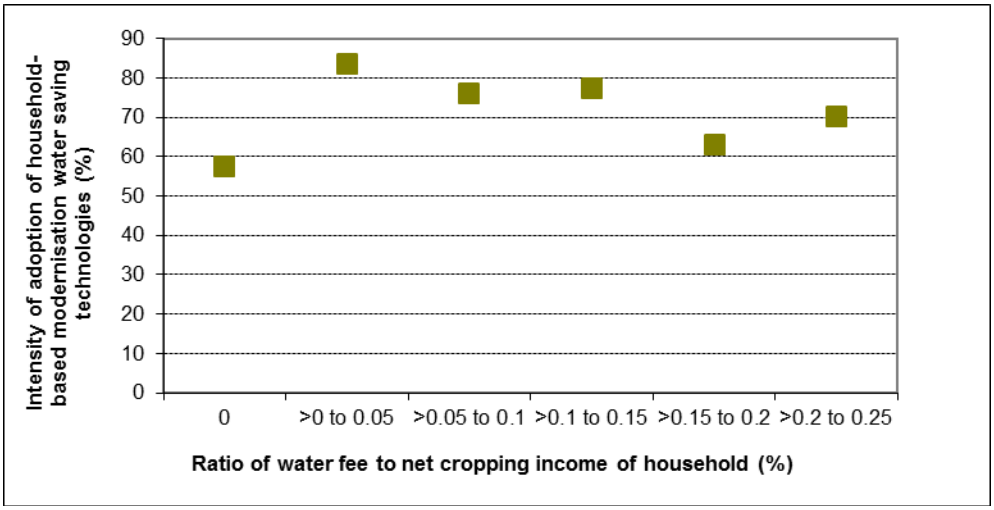

Figure 4. Relation between the ratio of water fee to net cropping income of household and the average intensity of adoption of household-based modern water-saving technology in China, 2010. Data source: Authors' survey.

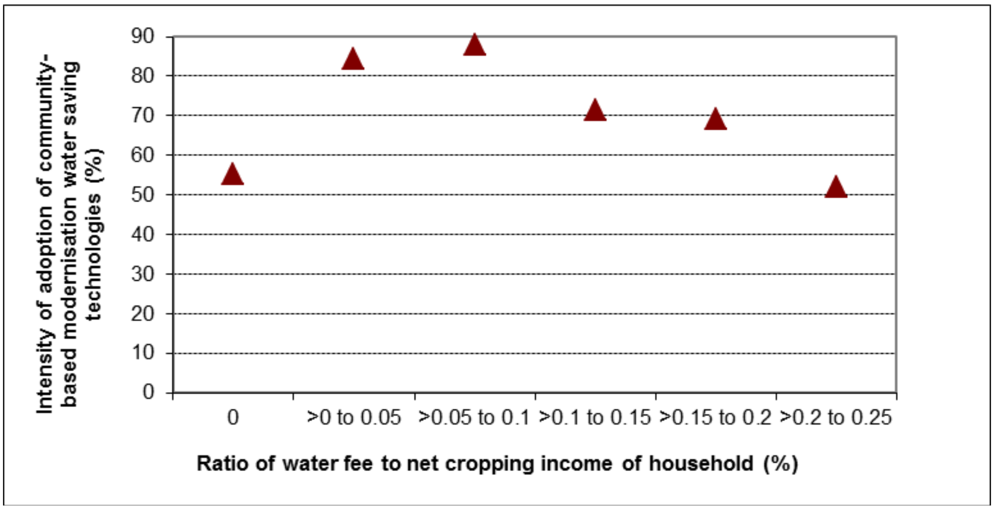

Figure 5. Relation between the ratio of water fee to net cropping income of household and the average intensity of adoption of community-based modern water-saving technology in China, 2010. Data source: Authors' survey.