Earth Syst. Dynam. Discuss., 5, 1543–1570, 2014
www.earth-syst-dynam-discuss.net/5/1543/2014/
doi:10.5194/esdd-5-1543-2014

Earth System Dynamics Discussions
Open Access

Policy support, economic incentives and the adoption of irrigation technology in China

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Received: 15 October 2014 – Accepted: 22 October 2014 – Published: 19 November 2014

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Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

The challenges China faces in terms of water availability in the agricultural sector are exacerbated by the sector's low irrigation efficiency. To increase irrigation efficiency, promoting irrigation technology has been emphasized by policy makers in China. The overall goal of this paper is to understand the effect of policy support and economic incentives on the adoption of irrigation technology in China. Based on a unique dataset collected at household and village levels from seven provinces in China, results indicated that household-based irrigation technology has become noticeable in almost every Chinese village. In contrast, only about half of Chinese villages have adopted community-based irrigation technology. Despite the relatively high adoption level of household-based irrigation technology at the village level, its actual adoption on crop-sown areas was not high, and it was even lower for community-based irrigation technology. The econometric analyses results revealed that policy supports via subsidies and extension services have played an important role in promoting the adoption of irrigation technology. Strikingly, the present irrigation pricing policy has played significant but contradictory roles in promoting the adoption of different types of irrigation technology. Irrigation pricing showed a positive impact on household-based irrigation technology, and a negative impact on community-based irrigation technology, possibly related to their substitution relationship, because having higher adoption of household-based irrigation technology reduce the incentives to invest in community-based irrigation technology. The paper finally concludes and discusses some policy implications.

1 Introduction

Increasing industrial and urban demands for water 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 2013 (Wang et al., 2005; MWR, 2013). 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., 2011; 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 figure is lower than that of some developed countries such as Israel (75 %) (Wang et al., 2010). Such low irrigation efficiency is one of the major reasons of increasing water scarcity in China. An improvement on irrigation efficiency is 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). Advanced irrigation technology can make a substantial difference in efficiency and contribute to the successful adaptation of the agricultural sector to climate change in China (Belder, 2004; Erenstein et al., 2008; Zhao et al., 2010; Zou et al., 2013a, b). However, the adoption level of irrigation technology is low in China (Blanke et al., 2007).

The Chinese Government stated that the promotion of advanced irrigation 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 5 year Plan highlight the importance of efficiency and technological innovation (CPC, 2011; USDA, 2011b). In addition, the Chinese Government announced expenditures of four trillion RMB (over USD 600 billion) on water conservation over 10 years starting in 2011 (Xinhua, 2011) and a specific investment of USD 6.03 billion to support the adoption of advanced irrigation technology on 2.53 million ha (Xinhua, 2012). There is clearly a strong policy

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commitment to diffusing advanced irrigation technology, but the likely impact of these interventions remains largely unknown.

The existing literature tells us that policy support is an important factor in farmers' decisions whether to adopt irrigation technology. Policies promoting adoption of irrigation 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 level of irrigation technology, especially when the prevailing adoption levels are low (Feder and Umali, 1993; Tiwari and Dinar, 2000). Liu et al. (2008) found a significant positive relationship between subsidies and adoption of some types of irrigation 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 level of irrigation technology (Dong, 2008; Feder and Umali, 1993; Ommani et al., 2009).

In addition to policy support, setting rational economic incentive for farmers is another important factor that influences farmers' technology adoption behavior. International experience indicates that water price is a significant determinant of adoption of irrigation 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 advanced irrigation 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 irrigation technology (Finlayson et al., 2008; Huang et al., 2010).

To design more effective policies to foster the adoption of irrigation technology in China, it is essential to answer the following questions: what are the current levels of extent and intensity of adoption of irrigation technology in rural China? Have interventions such as subsidy and extension policies played a significant role in promoting the adoption of advanced irrigation technology? Could economic incentives established through a water pricing policy play an important role on increasing the adoption level

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of irrigation technology? Despite a relatively rich international literature quantitatively analyzing the determinants of irrigation 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 irrigation 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 irrigation technology in rural China.

The overall goal of this paper is to understand the effect of policy support and economic incentive on the adoption of irrigation technology in China. With this goal in mind, the following objectives have been specified. First, we will examine the extent of adoption of irrigation 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 irrigation technology. Third, we will explore the influence of economic incentives (in terms of charges for irrigation water) on the adoption of irrigation technology.

The paper is organized as follows. The next section explains data sources. Section 3 presents current levels of adoption of irrigation technology. Section 4 shows the association between policy interventions and the adoption of irrigation technology. Section 5 describes the use of econometric models to explain the adoption extent and intensity of advanced irrigation technology. Section 6 discusses the results and Sect. 7 concludes with some remarks.

2 Data

The data used in this study are collected from one large-scale household 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 (Fig. 1). When selecting provinces for the field survey, we

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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. Because rainfed farmers do not need to pay irrigation fee – one of the key variables that we are interested, in the analysis we only focus on those farmers who replied on using irrigation for crop production. The final samples used in the analysis include 993 households in 118 villages in 20 counties.

In each village, we conducted two surveys, the household and the village surveys. While the household and village level surveys cover a wide range of issues, our analysis only used data relevant to this study. From the household level surveys, we used the following data: (i) whether adopted any kind of irrigation technology in each plot, and areas adopting irrigation technology, (ii) annual irrigation fee paid for each plot, (iii) the household characteristics, including the gender, age, and education of household heads, hours of total labor and off-farm labor, household assets, and production inputs and outputs for each plot that can be used for calculating net cropping income; and (iv) the plot characteristics, including crop sown area, soil type, soil quality, saline nature, topography and the distance from the households to the plot.

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From the village level surveys, we used the following data: (i) whether the households in the village adopted any kind of irrigation technology in their plots, (ii) whether the village obtained the financial subsidy for the adoption of irrigation technology, (iii) whether the village obtained extension service on adopting irrigation technology, such as extension experts coming to the villages to guide farmers, or the village being an experimental site for irrigation technology, (iv) the proportion of irrigated area, (v) the distance to township government, (vi) whether using groundwater for irrigation, and groundwater reliability in the past 5 years. Finally, we obtained the annual precipitation data for each county from the Chinese National Meteorological Information Center. Table 1 provides the descriptive statistics for the data used in the study.

3 Adoption of irrigation technology

For analytical convenience, Blanke et al. (2007) have divided irrigation technology into three groups: traditional, household-based and community-based. Traditional irrigation 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 irrigation technology is already widely adopted in China; they were used prior to the period of agricultural reform of the late 1970s and early 1980s. During the reform period, the adoption of traditional technologies grew slowly, in part due to the relatively high prevailing adoption level. When policy makers and scholars in China mention the adoption of irrigation technology, they mainly emphasize the adoption of household-based and community-based irrigation technology. Unlike traditional technology, these two categories of technology have begun to be adopted mainly since the 1980s. Given this observation, we refer to them as advanced irrigation technology. In our paper, we focus our discussion on the adoption of advanced irrigation technology.

As advanced irrigation technology, household-based and community-based irrigation technology has different characteristics. Household-based irrigation technology

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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 irrigation technology can be adopted separately by each household and have low fixed costs. Community-based irrigation technology includes 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 traditional and household-based irrigation technology, community-based irrigation technology has higher 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 two dimensions of the adoption of advanced irrigation technology: the extent of adoption, and its intensity. The extent of adoption measures how spatially pervasive the irrigation technology has become. To measure the extent of adoption, we apply the information collected at the village, household and plot levels. At the village level, we intend to reveal the percentage of villages that are adopting the irrigation technology. By our definition, if even a single household in the village adopts the irrigation technology, the village is considered to have adopted the technology. Similarly, even if a household uses a technology on only one plot, the household is considered as having adopted the irrigation technology. The extent of adoption at the household level is measured by the percentage of households adopting the irrigation technology. The extent of adoption at the plot level is measured by the percentage of plots adopting irrigation technology. To measure adoption intensity, we use the percentage of crop sown areas that adopt the irrigation technology.

Our data indicate that almost all villages in China have adopted the household-based irrigation technology. For example, 99 % of sampled villages adopted household-based irrigation technology in 2010 (Table 2, column 1). It implies that household-based irrigation technology has become a pervasive practice for famers to increase

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irrigation efficiency of agricultural activities. However, only 47 % of villages have adopted community-based irrigation technology (column 2).

Consistent with the village scale data, at household and plot scales the levels of adoption of household-based irrigation technology are much higher than that of community-based irrigation technology both. For example, 73 % of all households reported that they have adopted some type of household-based irrigation technology in 2010 (Table 2, column 1). On average, household-based irrigation technology was adopted in 54 % of plots. Turning to community-based irrigation technology, we find that only 17 % (Table 2, column 2) of households have adopted this category of irrigation technology and the percentage of plots adopting was only 14 % (column 2).

Despite the relatively high adoption level of household-based irrigation technology at the village and household level, its actual adoption on crop-sown areas is not high: roughly one third of crop-sown areas are utilizing this technology. The level of intensity of adoption for community-based irrigation technology is even lower. Our data reveals that in the full sample, community-based irrigation technology is used on only 4 % of crop-sown areas (Table 2, row 4). Our data are consistent with the findings of other researchers (such as Blanke et al., 2007; Liu et al., 2008). These prior studies found that the intensity of adoption of irrigation technology is very limited.

4 Policy support, economic incentives and the adoption of irrigation technology in China

Consistent with other studies (Dinar and Yaron, 1992; Ommani et al., 2009), descriptive statistical analyses show a possible positive relationship between the adoption of irrigation technology and policies encouraging it. In our analysis, we use two variables to represent policy support: a subsidy for investing in irrigation technology and extension services that assist farmers in becoming familiar with the application of irrigation technology. Based on our field survey, we found that 15 % 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 irrigation technology. For example, if the subsidy is available, 73 % of plots have household-based irrigation technology adopted; the adoption level is only 50 % if the subsidy is not available (Table 3, column 1). Similarly, if farmers can obtain the subsidy when they invest in irrigation technology, the adoption level of plots for community-based irrigation technology (29 %) is also considerably higher than without the subsidy (11 %) (column 2).

When the subsidy policy is available, the percentage of crop-sown areas to which irrigation technology is applied is higher. Specifically, in households where the subsidy is available, the average intensity of adoption of household-based irrigation technology is 77 % (Table 3, column 3), while the average intensity of adoption is lower (45 %) in those households where the subsidy policy is not available. In the case of community-based irrigation technology, the availability of subsidies makes also a difference, although smaller. If the subsidy is available, the average intensity of adoption of community-based irrigation technology is 24 % (column 4), while the figure is much lower (6 %) if the subsidy policy is not available. This smaller difference most likely arises because community-based irrigation 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 irrigation technology is higher. According to our field survey, 64 % of households had access to support activities from extension services. When extension services are available, 61 % of plots have household-based irrigation technology adopted, while the level of adoption is only 41 % if these services are not available (Table 3, column 1, last two values). Similarly, the availability of extension services is associated with a higher adoption level of community-based irrigation technology (18 vs. 8 %, column 2). Likewise, the provision of extension services also appears to increase the adoption intensity of irrigation technology. If the extension service activities are implemented, the adoption intensity of household-based irrigation technology increases from 42 to 50 % (column 3), but the adoption intensity of community-based

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irrigation technology remains at 8 % (column 4). Although the availability of extension services seems to have an impact on the intensity of adoption of household-based irrigation technology, the differences of values in Table 3 imply that the availability of subsidies may have a larger impact on the adoption of irrigation technology.

Payment for irrigation is an economic incentive that might lead to water conservation through the adoption of irrigation technology (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. Payment for irrigation is reflected by the ratio of irrigation fee to net cropping income of household (IFCI).

Our descriptive statistical analyses suggest the existence of a positive relationship between payment for water and the adoption of advanced irrigation technology. When there is a water fee, farmers make a notable positive difference in their plots, in terms of extent of adoption of household-based and community-based irrigation technology. For example, Table 4 (column 1) displays that in plots from households with values of IFCI larger than 0, the adoption extent of household-based irrigation technology is 12 % higher than among those plots in a no payment context. A milder increase (5 %) is visible in the extent of adoption of community-based irrigation technology (column 2); and less perceivable increases are visible for values of adoption intensity for both kind of irrigation technology (columns 3 and 4). When IFCI is larger than 0, we have divided the sample into four groups; each group has the same number of samples. Further analysis based on the four groups' data reveal that the positive relationship between the extent of adoption and adoption intensity of irrigation technology and the IFCI is still consistent with our above analysis.

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5 Specification of econometric methods for modeling adoption of irrigation technology

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

$$\boldsymbol{A}_{ijk} = \alpha + \beta \boldsymbol{S}_{ijk} + \gamma \boldsymbol{E}_{ijk} + \delta \boldsymbol{IFCI}_{ijk} + \lambda \boldsymbol{C}_{ijk} + \varepsilon_{ijk} \tag{1}$$

$$\boldsymbol{I}_{jk} = \alpha + \beta \boldsymbol{S}_{jk} + \gamma \boldsymbol{E}_{jk} + \delta \boldsymbol{IFCI}_{jk} + \lambda \boldsymbol{C}_{jk} + \varepsilon_{jk} \tag{2}$$

In Eq. (1), $\boldsymbol{A}_{ijk}$ represents adoption of irrigation technology for the ith plot of household j in village k. $\boldsymbol{A}_{ijk}$ is a dummy variable that equals 1 when the plot adopts the irrigation technology and 0 otherwise. Among the explanatory variables, $\boldsymbol{S}_{ijk}$, $\boldsymbol{E}_{ijk}$ and $\boldsymbol{IFCI}_{ijk}$ are the variables of interest. $\boldsymbol{S}_{ijk}$ is a qualitative dummy variable that represents the availability of subsidies to households for investing in irrigation technology; it equals 1 when the subsidy is available and 0 otherwise. Similarly, $\boldsymbol{E}_{ijk}$ is a dummy variable capturing the availability of extension service activities that equals one when the activities are available and 0 otherwise. $\boldsymbol{IFCI}_{ijk}$ is the ratio of the irrigation fee to net cropping income of the household; this variable expresses the importance of an annual per-area irrigation fee relative to the household's economic standing.

$\boldsymbol{C}_{ijk}$ is a set of control variables included to reduce omitted variable bias. It includes variables related to village, household and plot characteristics. Village variables include the proportion of irrigated area, the distance to the township government (km), the

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proportion of years without reliable groundwater supply in the last 5 years, a dummy variable reflecting the exclusive use of groundwater (1 = yes, 0 = no) and precipitation at the county level (mm). Household variables include the proportion of off-farm labors in the household, household assets (CNY 10 000), education (years), gender (1 = male, 0 = female) and age (years) of the head of household. Variables related to a particular plot include the distance from house to the plot (km) and six dummy variables (1 = yes, 0 = no) regarding various characteristics of the plot: loam soil, clay soil, plain terrain, high-quality, medium-quality and saline soil. 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 Eq. (2) for the Tobit model, $\boldsymbol{I}_{jk}$ represents intensity of adoption of irrigation technology for the jth household in village k, measuring the proportion of crop-sown areas adopting irrigation technology. Similar to Eq. (1), Eq. (2) also includes explanatory variables such as the availability of subsidies, the availability of extension service and $\boldsymbol{IFCI}$. In Eq. (2), the variables related to village and household characteristics are the same as those in Eq. (1). However, in Eq. (2) the variables related to the characteristics of the plots of the household are not the same. Instead, they are the average distance from the house to the various plots of the households (km), and six variables reflecting the proportion of the household's plots that exhibits a given characteristic. These six variables include the proportion of loam soil plots in the household (ratio), and five analogous variables describing the proportion of plots with the following characteristics: plain terrain, clay soil, high quality, medium quality and saline soil.

6 Estimation results and discussion

The estimated results of the four models show that they all perform well (Tables 5 and 6). The models passed the Chi-square test, and the Pseudo R^2 values of the four models range from 0.072 to 0.288. These values are sufficiently high for regression analyses based on large-scale cross-sectional data. Moreover, many village, household and

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plot 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 (Tables 5 and 6). This outcome implies that after keeping all other factors constant, farmers using groundwater exclusively are more likely to adopt advanced irrigation technology. 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 community-based irrigation technology with more extent and intensity, as expected. In the same way, adoption is positive and significantly related to plain terrain and plots with saline conditions. This relationship implies that irrigation technology is more likely to be adopted in plots with no slope conditions and can minimize the effects of soil salinity, which is consistent with previous findings (Castilla, 1999).

More importantly, our results demonstrate that the availability of subsidies has a positive and significant impact on adoption extent of both types of advanced irrigation technology (Table 5), and on adoption intensity of household-based technology (Table 6). The results show that when the subsidy policy is available to farmers, the farmers adopt irrigation technology with greater extent, and with greater intensity in the case of household based technology. 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 applied, the probability of adopting irrigation technology will increase by 11.7 % for household-based irrigation technology and by 2 % for community-based irrigation technology. Similarly, the probabilities of an increase in crop-sown areas using household-based irrigation technology are 10.6 %.

Similarly, in both logit and Tobit regressions, the coefficient of the extension service activities variable is positive and statistically significant for household-based irrigation technology. This result suggests that when extension service activities are accessible to farmers, the probability that farmers adopt household-based irrigation technologysignificantly increases. This is in agreement with previous findings in the

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literature (Dong, 2008; Feder and Umali, 1993; Ommani et al., 2009). If extension service activities are available, the possibility of adopting household-based irrigation technology increases by 10.6 %, and the probability of increase in crop-sown areas is 10.2 %. The lack of impact of the policy on community-based irrigation technology is related to the fact that the decision to adopt community-based technology might be highly influenced by local leaders – village, township and even county leaders.

Having a stronger economic incentive significantly facilitated farmers adopting household-based irrigation technology, but hindered the adoption of community-based technology. The estimated coefficient of the IFCI is positive and statistically significant in the model of household-based irrigation technology (Table 5, column 1). It implies that when farmers need to pay higher irrigation fees in relation to their limited net cropping income, they are more concerned about the adoption of household-based irrigation technology, which is expected to reduce the application of irrigation and relevant production inputs for irrigation. Our result implies that farmers are responsive to an irrigation price policy on their decision on adoption of household-based irrigation technology. If the price has been set well, it can play significant role on inducing farmers to change their irrigation behavior. This result is consistent with previous studies from Caswell et al. (1990), and Dinar and Yaron (1992). However, an interesting finding is that the coefficient of IFCI in the model of community-based irrigation technology (column 2) is negative and also significantly. This result indicates that having higher irrigation fee ratio will hinder the adoption of community-based irrigation technology. An explanation for this is that there is some substitution effect between household and community-based irrigation technology. If farmers have higher incentives to adopt household-based irrigation technology, there will be fewer incentives to invest in community-based irrigation technology, which has an added barrier for adoption due to its high costs. Finally, our results have not indicated the significant role of economic incentives on increasing adoption intensity of irrigation technology (Table 6).

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7 Concluding remarks

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

The results of our analysis reveal that policy support has played an important role in promoting the adoption of irrigation 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 irrigation technology. However, only 15 % of households 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 also makes a significant contribution. The extension programs should be continued or even extended.

Compared with policy support, the present irrigation pricing policy has played a very important role in promoting the adoption of household-based irrigation technology. Our results show that the payment for water and the adoption level of household-based irrigation technology are positively and significantly related. Interestingly, the impact of irrigation pricing on the extent of adoption of community-based irrigation technology shows significant and negative values. It implies that there is a substitution relationship between household and community-based irrigation technology. In fact, such relationship further indicates the significant role of irrigation pricing policy on promoting the adoption of irrigation technology. Compared with community-based irrigation

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technology, household-based irrigation technology is cheaper and easier to adopt by small and individual farmers, which is more consistent with present production environment in China. Therefore, instead of investing in expensive community-based irrigation technology, the government should put more efforts on encouraging farmers to adopt household-based irrigation technology. In China, there is still much opportunity space for inducing farmers to adopt household-based irrigation technology through applying rational economic incentives, such as irrigation pricing policy.

Acknowledgements. The authors thank Lijuan Zhang, Yumin Li, Yake Liu and Chen Huang for their support in survey translation and data cleaning; Ian Holman, David Zilberman, Ai Xiaoqing, Richard Hardiman, Christopher J. Perry and Wilko Schweers for their comments; Maarten Buis, Nick Cox and Tirthankar Chakravarty for their econometric suggestions; Xiong Wei for the remote sensing data; Marie Paul Benassi, Simon Spooner, Paul van Meel and Lars Skov Andersen from the European Union delegation in Beijing for their interesting background comments. We acknowledge financial support from the Max Planck Institute for Meteorology, the Kompetenzzentrum Nachhaltige Universität from Hamburg University, the PROMOE program of the Universitat Politècnica de València, the National Natural Sciences Foundation of China (71161140351 and 91325302), the Chinese Ministry of Science and Technology (2012CB955700), Institute of Geographical Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (2012ZD2008).

The service charges for this open access publication have been covered by a Research Centre of the Helmholtz Association.

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Table 1. Descriptive statistics for major variables included in the study.

	Mean	SD
Village level variables		
Financial subsidies (1 = Yes; 0 = No)	0.15	0.36
Extension service (1 = Yes; 0 = No)	0.64	0.48
Proportion of years without reliable water supply	0.05	0.21
Exclusive use of groundwater (1 = Yes; 0 = No)	0.14	0.35
Proportion of irrigated area	0.71	0.28
Distance to township government (km)	5.97	5.24
County level variable		
Precipitation (mm)	1078	336
Household level variables		
Adoption of advanced community based water saving technology (1 = Yes; 0 = No)	0.49	0.50
Adoption of advanced household based water saving technology (1 = Yes; 0 = No)	0.11	0.31
Ratio of irrigation fee to net cropping income (ratio)	0.01	0.03
Amount of irrigation fee (CNY ha^{-1})	26.03	40.61
Proportion of household area adopting advanced community based water saving technology	0.55	0.40
Proportion of household area adopting advanced household based water saving technology	0.16	0.35
Gender of household head (1 = Male; 0 = Female)	0.99	0.11
Age of household head (years)	52.67	10.53
Education of household head (years)	6.80	2.97
Proportion of off-farm labour	0.27	0.28
Household asset (CNY 10 000)	13.50	30.19
Plot level variables		
Crop sown area (ha)	138.11	564.85
Loam soil (1 = Yes; 0 = No)	0.24	0.43
Clay soil (1 = Yes; 0 = No)	0.43	0.50
Plain terrain (1 = Yes; 0 = No)	0.67	0.47
High quality plot (1 = Yes; 0 = No)	0.19	0.39
Medium quality plot (1 = Yes; 0 = No)	0.67	0.47
Saline plot (1 = Yes; 0 = No)	0.03	0.18
Distance from house to plots (km)	0.74	0.75

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Table 2. The adoption extent and intensity of advanced irrigation technologies in China, 2010.

	Household-based technology	Community-based technology
Adoption extent		
Percentage of villages (%)	99	47
Percentage of households (%)	73	17
Percentage of plots (%)	54	14
Adoption intensity		
Percentage of crop sown areas (%)	32	4

Data source: authors' survey.

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Table 3. Relationship between policy support and adoption of advanced irrigation technology in China, 2010.

	Adoption extent: share of plots adopting (%)		Adoption intensity: share of crop sown areas adopting (%)	
	Household-based technology	Community-based technology	Household-based technology	Community-based technology
Financial subsidy				
Available	73	29	77	24
Not available	50	11	45	6
Extension service				
Available	61	18	50	8
Not available	41	8	42	8

Data source: authors' survey.

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Table 4. Relationship between economic incentives and adoption of advanced irrigation technology in China, 2010.

	Adoption extent: share of plots adopting (%)		Adoption intensity: share of crop sown areas adopting (%)	
	Household-based technology	Community-based technology	Household-based technology	Community-based technology
Ratio of irrigation fee to net cropping income				
0	47	11	45	7
> 0	59	16	49	8
Among samples*:				
> 0–0.002	60	17	46	4
0.002–0.005	60	17	59	19
0.005–0.011	60	18	61	19
> 0.011	56	15	58	19

* When the ratio of irrigation fee to net cropping income is larger than 0, we have divided the sample into four groups by their ratio of irrigation fee to net cropping income; each group has the same number of elements.
Data source: authors' survey.

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Table 5. Estimates of determinants of the adoption decision of advanced irrigation technology in China (Logit model).

	Whether the plot adopts (1 = Yes; 0 = No)	
	Household-based irrigation technology	Community-based irrigation technology
Policy support		
Financial subsidies (1 = Yes; 0 = No)	0.117***	0.020**
	(4.71)	(2.11)
Extension service (1 = Yes; 0 = No)	0.106***	0.008
	(5.43)	(0.98)
Economic incentives		
Ratio of irrigation fee to net cropping income	1.346***	−0.822***
	(3.77)	(3.74)
Village characteristics		
Proportion of irrigated area	0.276***	0.093***
	(7.79)	(6.19)
Distance to township government (km)	0.001	−0.000
	(0.40)	(0.59)
Proportion of years without reliable water supply	0.015	0.003
	(0.31)	(0.23)
Exclusive Use of groundwater (1 = Yes; 0 = No)	0.100***	0.080***
	(2.94)	(6.68)
Annual total precipitation (mm)	−0.0001**	−0.0001***
	(2.01)	(5.05)
Household characteristics		
Gender of household head (1 = Male; 0 = Female)	−0.141*	−0.018
	(1.84)	(0.71)
Age of household head (years)	−0.002**	−0.000
	(2.18)	(0.01)
Education of household head (years)	0.005	0.005***
	(1.54)	(4.09)
Proportion of off-farm labour	−0.017	0.057***
	(0.56)	(5.25)
Household asset (CNY 10 000)	0.001***	0.0001***
	(2.65)	(2.78)
Plot characteristics		
Loam soil (1 = Yes; 0 = No)	−0.046**	0.010
	(1.98)	(1.12)
Clay soil (1 = Yes; 0 = No)	−0.056***	−0.015*
	(2.86)	(1.96)
Plain terrain (1 = Yes; 0 = No)	0.002	0.040***
	(0.12)	(4.21)
High quality plot (1 = Yes; 0 = No)	0.044	0.026**
	(1.48)	(2.25)
Medium quality plot (1 = Yes; 0 = No)	0.059**	0.020**
	(2.44)	(2.02)
Saline plot (1 = Yes 0 = No)	0.092**	0.050***
	(2.00)	(4.06)
Distance from house to plots (km)	0.039***	−0.011**
	(3.42)	(2.01)
Observations	4172	4172
Prob > chi^2	0	0
Pseudo R^2	0.0720	0.2880

Notes: Estimates are marginal effects. Absolut value of z statistics in the parenthesis.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Data source: authors' survey.

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Table 6. Estimates of determinants of the adoption intensity of advanced irrigation technology in China (Tobit model).

	Proportion of crop sown areas adopting	
	Household-based irrigation technology	Community-based irrigation technology
Policy support		
Financial subsidies (1 = Yes; 0 = No)	0.106***	0.130
	(2.69)	(1.47)
Extension service (1 = Yes; 0 = No)	0.102***	0.043
	(3.12)	(0.49)
Economic incentives		
Ratio of irrigation fee to net cropping income	−0.003	−1.223
	(0.01)	(0.94)
Village characteristics		
Proportion of irrigated area	0.247***	0.867***
	(4.33)	(5.18)
Distance to township government (km)	−0.002	0.009
	(0.67)	(1.17)
Proportion of years without reliable water supply	0.028	0.056
	(0.47)	(0.40)
Exclusive use of groundwater (1 = Yes; 0 = No)	0.175***	0.411***
	(3.29)	(3.67)
Annual total precipitation (mm)	−0.0001***	−0.001***
	(5.52)	(7.32)
Household characteristics		
Gender of household head (1 = Male; 0 = Female)	0.036	0.080
	(0.41)	(0.41)
Age of household head (years)	−0.001	0.002
	(0.72)	(0.52)
Education of household head (years)	0.005	0.035**
	(0.88)	(2.40)
Proportion of off-farm labour	−0.021	0.199
	(0.40)	(1.48)
Household asset (CNY 10 000)	0.000	0.002**
	(0.56)	(2.40)
Plot characteristics		
Proportion of loam soil plots	0.060	0.317***
	(1.33)	(2.68)
Proportion of clay soil plots	0.103***	0.085
	(2.86)	(0.90)
Proportion of plain terrain plots	0.112***	0.254**
	(2.93)	(2.31)
Proportion of high quality plots	0.004	0.226
	(0.07)	(1.45)
Proportion of medium quality plots	−0.013	0.210
	(0.26)	(1.57)
Proportion of saline plots	0.074	0.305*
	(0.97)	(1.89)
Distance from house to plots (km)	−0.018	−0.036
	(0.89)	(0.57)
Observations	993	993
Prob > chi^2	0	0
Pseudo R^2	0.1686	0.2644

Notes: Estimates are marginal effects. Absolut value of z statistics in the parenthesis.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Data source: authors' survey.

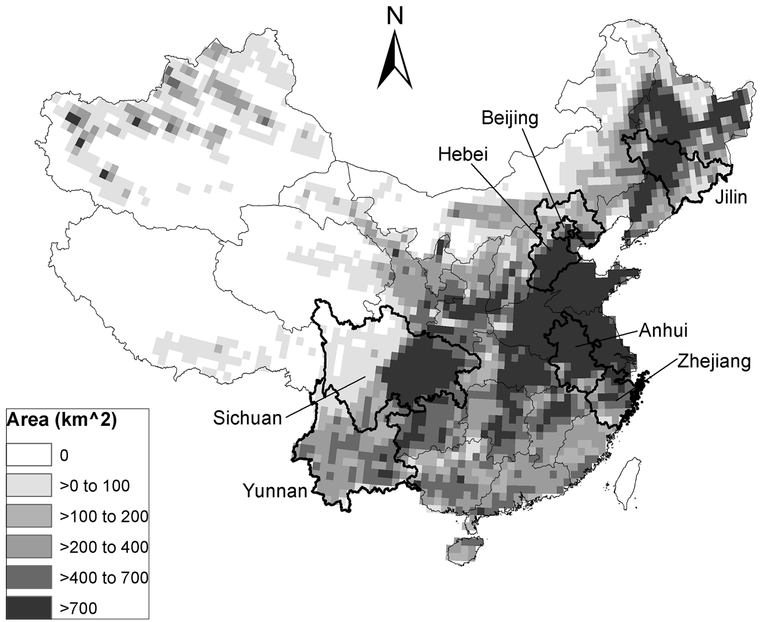

Figure 1. Map of China illustrating the surveyed provinces in bold over pixels showing density of square kilometers of total sown area of rice, wheat, maize and soy in 2000. Source: authors, using data from Qiu et al. (2003).

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