# Technical efficiency in small-scale irrigation cooperative and its determinants from the perspective of social capital heterogeneity–the case of northwestern China

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Abstract

Increased attention has recently been given to technical efficiency of small-scale irrigation to achieve food security and increase agricultural development. In this paper, the authors classify irrigation supply management methods as cooperative or non-cooperative, introduce social capital by four dimensions (social network, social trust, social reputation, and social participation), and highlight the impacts of both social capital and cooperative agreements on technical efficiency in the context of small-scale irrigation management. Efficiency is assessed using data envelopment analysis (DEA), and the impact of cooperative agreements and social capital on efficiency is estimated using path analysis. The result of DEA indicates that cooperative and social capital can improve technical efficiency of irrigation. Results of path analysis show that the presence of a cooperative has a positive, significant and direct impact on efficiency. Additionally, the effect of social capital on efficiency is estimated to be reinforced via participation in cooperative methods.

Keywords

Technical efficiency; Cooperative agreement; Social capital; Small-scale irrigation

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## 1. Introduction

Agricultural irrigation infrastructure, as the main consumptive production device, is critical for water security, agricultural development, and continued production. Rosengrant et al. (2002) state that “irrigated agriculture will account for 72 percent of total water withdrawal” and also “account for 44 percent of total agricultural production in 2025”. The world will not achieve food security without significant increases in water use efficiency (FAO, 2006), especially in the context of irrigation. Northwestern China is a typical case where water scarcity and food security are increasing problems, and the imbalance between supply and demand is important issues (Huang et al., 2012). Accordingly, approaches that optimize efficiency and irrigation supply management in Northwest China are needed.

Cooperative supply is a potential way to develop small-scale irrigation facilities (Baker, 1998; Ostrom, 2000; He and Luo, 2006) because an individual typically cannot afford the expensive small-scale irrigation device, and a cooperative will help defray their costs and provide irrigation supplements. About fifty-eight percent of small-scale irrigation facilities in China are supplied by cooperatives (Wang, et al., 2007; Huang, et al., 2012). Hence, comparing efficiency between cooperative and non-cooperative will allow the identification of mechanisms that contribute to the success of small-scale irrigation supply management.

The neoclassical theory of the firm assumes that products and producers are homogeneous. In reality, producer characteristics like social capital can be quite heterogeneous. The impact of social capital and cooperatives has been shown to be especially important in irrigation projects (Tatlonghari and Sumalde, 2006).

Water issues have received considerable attention in economic literature of late. The majority of the research has focused on detriments of irrigated water use efficiency, including the impacts of such factors as education level (Karagiannis et al., 2003), water price (Wang and Li, 2005), farmer households’ size and the age of the head of household (Dhehibi et al., 2007), and irrigated areas (Speelman et al., 2006).  Absent from this literature is an assessment of the impacts of cooperatives and social capital on the technical efficiency of irrigation.

This paper introduces supply management and social capital as two important explanatory variables in determining efficiency. The first goal of this paper is to measure and compare the irrigation supply method—cooperative and non-cooperative in terms of their relationship to the technical efficiency of irrigation which is measured using Data Envelopment Analysis (Coelli, 1996). The second goal is to examine the relationship among social capital, cooperation, and technical efficiency. This will be accomplished using path analysis. The analysis is based on a sample of 888 farmer households from the Guanzhong Plain in Shaanxi Province, China. This area is an example of small-scale irrigation in rural China.

The structure of this paper is as follows: first we construct a theoretical framework including the conceptualized definition and hypothesis; second, measure methods and data collection are described; third, we calculate technical efficiency of irrigation by cooperative and non-cooperative, as well as social capital, and estimate its determinants; and finally, conclusions are given.

## 2. Theoretical Framework

Our definition of a "small-scale irrigation" system follows the common definition in China (Lv, 2010). In China, small-scale irrigation refers to water conservation facilities and rural water supply projects for the purposes of irrigation, flood control, and storage. Such facilities include small-scale water resource engineering, irrigation channels and accessory, and small pumping stations. Our definition of "cooperative" is any collection of individual farmers organized to supply small-scale irrigation.

This study focuses on systems consisting of a groundwater well with pumping and canals to the farmland. This type of irrigation system is popular in Northwest China. In 2007, on average, 37% of China's total water supply came from groundwater based on this kind of system (Ministry of Water Resources 2008; Huang et al., 2012). Although the central government invests in a large number of irrigation systems, current supplies of irrigation water cannot match the demands of farmers for irrigation in Northwest China (Zhang and Zhang 2001). It is only through a cooperative that the gap between irrigation water supply and demand can be narrowed in rural areas of China (He and Luo, 2006).

In practice, it is a difficult task for many farmer households to supply small-scale irrigation cooperatively. Several roadblocks exist to wider application of cooperative irrigation systems. First, the willingness of farmers to cooperatively supply irrigation is hampered by the incompatible roles of elite farmers, who are leading agricultural development in rural areas. Second, high organizational costs and transaction costs often contribute to an inability to allocate costs equitably among users. Meanwhile, low efficiency and lack of incentives also affect long-term cooperative supply.

This dilemma of collective action has received some attention in the literature. Some explain this phenomenon from the perspective of social capital (Putnam, 2000; Krishna, 2002; Titeca and Vervisch, 2008). Social capital is, to some extent, understood as a resource or attribute of individuals that enables them to enhance their collective action (Ostrom and Ahn, 2009; Gorton et al., 2010; Gutiérrez et al., 2011) by lowering transaction costs and accumulating social learning (Uphoff and Wijayaratna, 2000), and improve efficiency (Sampson et al., 1997; Lochner et al., 1999; Gerlie et al., 2006; Anil Rupasingha et al., 2006).

Previous literature has investigated social capital as a mechanism for increasing technical efficiency. For example, Paxton (1999) defines social capital as a network to gain access to resources (similar to Bourdieu, 1983; Putnam, 1995). Others define social capital as the process of building mobile resources to use water collectively (Granovetter, 1973; Wilson, 1987; Uphoff and Wijayaratna, 2000). Portes and Sensenbrenner (1993) discuss social reputation as the main method of social capital formation which additionally provides more social support for the individual and organization. Coleman (1998) finds that social norms and social trust, as well as participation, are important components of social capital (see also Brehm and Rahn, 1997; Rose, 1999; Onyx et. al., 2000; Neira et al., 2009; Guillen et al., 2011). Although the concept of social capital varies, these definitions of social capital evoke framers' consciousness toward more effective practices and avoidance of conflict in the interest of mutual benefits (Putnam, 1995).

Social capital has been criticized as consisting of "vague ideas" and "casual empiricism" (Solow 1999). However, Solow mainly focuses on one or several indicators but falls short of precisely conceptualizing social capital's components. It is impossible to explore the nature of interaction between the different components of social capital (Newton, 1997). Part of the problem lies in the conflict of institutions with different forms of social capital (Dasgupta and Serageldin, 2000). The majority of researchers have argued that the combination of multiple dimensions of social capital could be more effective in addressing common dilemmas and enhancing people's wellbeing (Woolcock, et al., 2002; Pretty, 2003).

Van Oorschot et al. (2012) also emphasize that social capital is a combination of different definitions rather than a single unified concept. Hence, we synthesize their concepts and choose four dimensions (social networks, social trust, social reputation and social participation) to describe farmers' social capital and construct a social capital index. This index will be used to evaluate the amount of social capital owned by farmers (Lu and Wang, 2012).

Whereas social network indicates the interaction of farmers in their communities (Putnam, 2000) and social trust refers to trust towards people in general or to specific social groups (Uslaner and Conley, 2003), social reputation describes the extent to which an individual is respected in his/her community (Lu and Wang, 2012). Social participation refers to the involvement of individuals in formal and informal collective issues of their community (Putnam, 2000). Interaction among members generated by different dimensions of social capital is necessary to achieve efficiency (Tatlonghari and Sumalde, 2006). In this paper, a social network represents the relationships and interactions with other people based on Bian's (2003) definition of social networks based on network size, network density, and network diversity. Information on these factors was collected using fifteen questions including network size--how many persons do you usually contact with per week and how many persons will help you when you face difficulties; network density--the frequency of communication with family members, friends, relatives, village leaders, neighbors, agricultural organization, and respected farmers by using a Likert scale from one to five; network diversity--what do your friends, your family members, and relatives do, and how much wealth do they own. Social trust refers to the trust decision makers have in different persons as defined by

Stolle (1998). Social trust is the value that farmers place on other people's trust and is measured using nine questions; rating the extent to which a farmer trusts family members, friends, relatives, neighbors, village leaders, agricultural organizations, respected farmers, common persons, and strangers using a Likert scale from most distrust to most trustable. Social reputation is often thought to be the foundation of cooperation in rural communities and refers to the extent in which one is respected by other persons (Wang et al., 2012). We use six questions to measure social reputation: how much a farmer is respected, how many persons will help you when you are busy in wedding preparation, building a house, harvest, facing difficulties, and contradictions (similar to Lu and Wang, 2012). Social participation is defined as the ability of explaining their opinions (Szreter, et.al, 2004), and the information on social participation is collected using five questions. Social participation is measured on a Likert scale from one to four rating the participation frequency of village collective affairs including water issues, meetings, elections, "one issue one meeting", as well as how often the farmer proposes suggestions.

In our study, technical efficiency of irrigation is defined as the ratio of ideal expense to the actual irrigation expense under the condition of other inputs and outputs being fixed. Assume farmer *i* produces product *Y* by using inputs *X* and irrigated water expense *W,* based on the production function *Y=f(X, W)*. Holding other inputs and outputs fixed, the formula for technical efficiency is:

$$WE = Min\{\mu : f(X, \mu W) \geq Y(\hat{W})\} = \hat{W} / W, \quad (1)$$

Where $\mu$ indicates the scale parameter of inefficiency water expenditure, *W* is actual water expense, $\hat{W}$ is the ideal water expense (including the construction fees and water consumption fees), and *WE* is technical efficiency. $WE \in [0, 1]$, when *WE*=1, it means the use of water resources is optimal; as *WE* decreases, irrigation efficiency also decreases.

Based on this conceptual framework we are concerned with two groups (a) non-cooperatives: farmers who do not participate in cooperative construction and supply, which means the group will not invest in small-scale irrigation; and (b) cooperatives: farmers who participate in a cooperative, that is, a few members who invest in small-scale irrigation together and use it collectively. In this paper, we focus on the construction of wells and water distribution systems.

To this end, we are concerned with testing two hypotheses regarding the technical efficiency of irrigation.  A cooperative is beneficial to farmers by decreasing transactions and monitoring costs. Members in cooperation create trust and develop a reputation with each other. When farmers coordinate with water issues, trustworthiness and reputation among them make coordination easier to achieve mutual aims. To test this proposition, we estimate the efficiency of the different groups. If the technical efficiency is higher in cooperative than non-cooperative setting, this would indicate that cooperative membership improves the efficiency of irrigation. Thus, our first hypothesis is:

*H1. Cooperatives will not increase technical efficiency of irrigation.*

Rejection of this null hypothesis would lead to the conclusion that cooperatives enhance efficiency.

Social capital can generate trust and foster interaction, as well as enlarge the resource base a community may use. This decreases transaction costs and allows for coordination of costs through sharing of information. At the same time, the trust and interaction will foster cooperative formation. Thus, we anticipate that social capital improves efficiency as well as cooperative participation. The more one owns social capital, the higher efficiency score he or she can expect. Hence, our second null hypothesis is:

*H2. Social capital is not sine qua non to increase efficiency.*

Based on our goals and hypotheses, the whole framework is shown as figure 1.

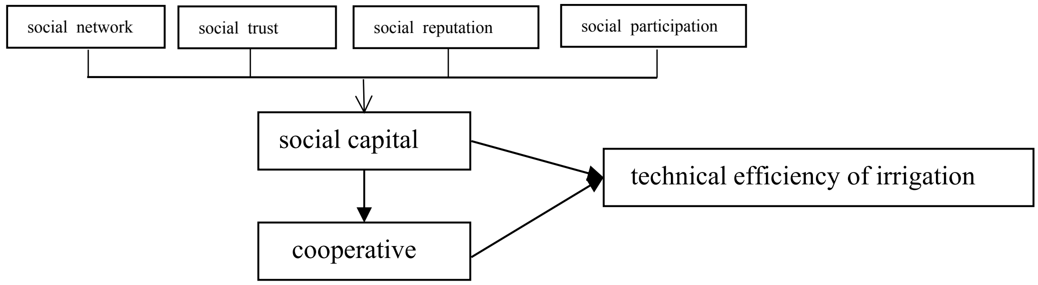



Figure 1. Theoretical Framework

3. Data Collection and Description

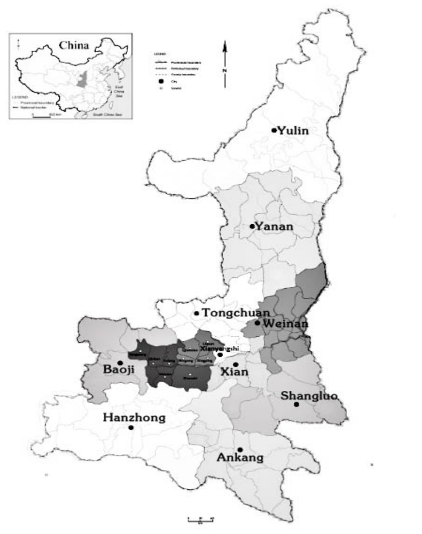



Figure 2. Location of Study Areas in Shaanxi Province (source from Miao et al., 2012)

The data on farmer households' agricultural production and social capital were collected in Guanzhong Plain of Shaanxi Province, China (Figure 2). Irrigated lands in this region account for 75% of the total arable land and are primarily dedicated to corn and wheat production. The primary source of irrigation water in the Guanzhong Plain is groundwater wells. This area is facing a water scarcity problem. Small-scale irrigation is common and well-organized by different groups. The survey was carried out between April and June in 2011(Miao et al., 2012). Multistage random sampling was used to do this survey. Six zones, namely Fengxiang, Qishan, Meixian, Fufeng, Wugong, and Zhouzhi were chosen to provide a sample of systems that were constructed collectively in areas with diverse social capital. A total of 900 farmers were randomly selected from six districts. From each district, five villages were selected randomly. Finally, twelve samples were omitted due to vacant answers and 888 data were left to be analyzed. The questionnaire includes basic characteristics of farmers, including age, gender, education level, agricultural income, position, agricultural production costs, water expense, irrigation area, agricultural labor, and a series of questions about social capital. The questionnaire was administered by personal interview. The classification by type (participation in a cooperative) is done on the basis of whether the farmer makes contributions to small scale irrigation construction. Both questionnaires take one and a half or two hours to complete.

Table 1 Farmer's Characteristics

| | | Cooperative Supply | Non-cooperative Supply | Cooperative to Non-cooperative(%) |
|---|---|---|---|---|
| | | 573 (64.53) | 315 (35.47) | 81.9 |
| Gender | male | 316 (55.15) | 166 (52.7) | 90.36 |
| | female | 257 (44.85) | 149 (47.3) | 72.48 |
| Education level | illiterate | 10 (1.74) | 10 (3.17) | 0 |
| | primary | 209 (36.47) | 122 (38.73) | 71.31 |
| | secondary | 297 (51.83) | 154 (48.9) | 92.86 |
| | higher | 32 (5.59) | 19 (6.03) | 68.42 |
| | college and above | 25 (4.37) | 10 (3.17) | 150 |
| Position | village leader | 16 (2.79) | 4 (1.27) | 300 |
| | team leader | 31 (5.41) | 11 (3.49) | 182 |
| | villager | 526 (91.8) | 300 (95.24) | 75.33 |

Note: percentages are presented in parentheses.
Source: Field Survey, 2011.

The summary statistics of the survey sample are shown in tables 1 and 2. The majority of farmer households participate in a cooperative irrigation supply system. Cooperative farmers account for 64.53% of the sample, and more than three-fourths of samples achieved at least a secondary level of education. Average agricultural income for the sample of farmers participating in cooperative supply is 7,263.28 yuan, which is higher than the average income of the farmers who do not participate in a cooperative supply. The average water expense and agricultural production costs for those who participate in a cooperative supply is 885.58 yuan and 2,439.86 yuan respectively, 11.71% and 3.61% lower than the same costs for farmers who do not participate in a cooperative supply. Irrigation area and agricultural labor of cooperative supply is higher than those of non-cooperative supply by 10.22% and 2.0% respectively. Social capital of cooperative supply is higher in comparison to social capital of non-cooperative supply, nearly 153.84%.

Table 2 Social-economic Characteristics of Respondents

| | Cooperative Supply | | Non-cooperative Supply | | Cooperative to Non-cooperative (%) |
|---|---|---|---|---|---|
| | Means | Std Error | Means | Std Error | |
| Agricultural income (yuan) | 7263.28 | 7942.078 | 6729.2 | 8040.5 | 7.94 |
| Agricultural cost (yuan) | 2439.86 | 2343.9 | 2531.45 | 2173.22 | -3.61 |
| Water expense (yuan) | 885.58 | 885.78 | 1003.07 | 1472.91 | -11.71 |
| Irrigation area (mu) | 3.99 | 3.61 | 3.62 | 2.68 | 10.22 |
| Agricultural labor (person) | 2.04 | 1.04 | 2.00 | 0.91 | 2.0 |
| Social capital (score) | 0.07 | 0.85 | -0.13 | 0.51 | 153.84 |

Source: Field Survey, 2011.

## 4. Methodology

### 4.1. Factor Analysis

Factor analysis is a mathematical modeling technique to examine a wide range of data sets. It proposes an explicit underlying model that attempts to interpret correlations among a set of *n* observed variables ($X_1, X_2,...X_n$) through the linear combination of a few latent (unobserved) random factors ($F_n$). In the case of a single factor, F, the underlying model is defined as:

$$X_n = \lambda_n F + e_n \qquad (2)$$

where $\lambda_n$ is the loading factor associated with the observed variable $X_n$, and $e_n$ is an independently distributed error term with zero mean and finite variance. The loading factors provide information on the correlation between each variable and common factor; the higher the load, the more relevant the primary variable is in defining the dimensionality of a factor (Clark et al., 2004).

Social capital is a latent variable which is unobservable. Here, in order to obtain a measurable value for social capital, social capital is divided into four aspects: social network, social trust, social reputation, and social participation. As mentioned in section 2, we ask all the questions and all the answers are collected by personal interviews.

### 4.2. Data Envelopment Analysis Model

Data envelopment analysis (DEA) is a nonparametric analysis tool to study input-output efficiency (Coelli et al., 2002; Dhungana et al., 2004; Speelman et al., 2008). The DEA model relies on the principle of Pareto Optimality, and uses a linear programming approach to determine the optimal production possibilities frontier. The combinations of inputs and outputs are called the decision making unit (DMU). If a DMU is on the frontier of the production possibility, it will have an efficiency score of one.

The DEA method is a widely used technique for estimating efficiency. DEA does not require setting specific behavioral assumptions or parameters of the structural relationship between inputs and outputs (Kumbhakar and Lovell, 2000). The DEA model can explain the decision-making unit's efficiency as well as providing a calculation of each DMU's input or output targets.

The DEA approach can be used as an output-oriented or input-oriented measurement. Since our focus is on the efficiency of the allocation of water resources in agricultural production, an input-oriented approach is taken here. The DEA model can be analyzed under conditions of constant returns to scale (CRS) or variable returns to scale (VRS). Here we use DEA to estimate the efficiency of the allocation of water resources under the assumption of VRS, which is devoid of scale efficiency effects (Coelli, 1996). Since the current study is only concerned with inefficiency in the use of other fixed inputs excluding irrigated water expense, sub-vector variation of DEA is used (Lilienfield and Asmild, 2007) .The DEA model is specified as:

$$\mathrm{Min}_{\theta,\lambda}\theta^{w} \tag{3}$$

Subject to:

$$\begin{aligned}
&-\mathrm{y}_i + Y\lambda \geq 0;\\
&\theta^{w} x_i - X^{w}\lambda \geq 0;\\
&x_i^{n-w} - X^{n-w}\lambda \geq 0;\\
&NI'\lambda = 1;\\
&\lambda \geq 0
\end{aligned}$$

Here $\theta^w$ refers to the efficiency score for the *i*-th farmer, $\lambda$ is a vector of constants, $x_i$ and $y_i$ represent input and output for the *i*-th farmer, $X$ and $Y$ are the N order input and output matrixes respectively, $x^w$ is the water expense input, $x^{n-w}$ is other inputs, $NI'$ is N unit vector, and NI'λ =1 indicates that constraint three is a convexity constraint, which indicates variable returns to scale.

Here the analysis is based on one output and four inputs in this analytic method listed as follows.

(1) Output: farmers' agricultural revenue (collected by the average revenue of every farmer)

(2) Input: water expenses (including irrigation water consumption fees and constructions fees); agricultural production costs (including fertilizer, seed, and machinery fees); irrigation area (the area that is irrigated); agricultural labor (the number of full-time farmers and employees). All the data is continuous.

### 4.3. Path Analysis

Path analysis is a useful approach to quantifying and interpreting causal theory by analyzing the total effects and indirect effects among variables (Duane and Robert, 1975). This paper uses path analysis to analyze the relationship among social capital heterogeneity, cooperative agreements, and the technical efficiency of water expenditure. The procedure builds on an applied iterative scheme, which involves the systematic use of recursive equations (Hauser et al., 1975). We can demonstrate direct and indirect effects based on coefficients of each structural equation. Indirect effects refer to the parts of total effects transmitting some causal effects of prior variables onto the subsequent variables by intervening variables (Rex, 2011). The direct effect of one variable on another is part of its total effect which is not transmitted via intervening variables (Duane and Robert, 1975).

This paper uses multiple dummy variables: "COOP" is used to indicate whether or not the DMU is part of a cooperative (zero if no, one if yes); "AGE" is a dummy variable (16-26=1; 27-36=2; 37-46=3; 47-56=4; 57-66=5; 67 and above=6); "GENDER" is a dichotomous dummy variable (zero if female, one if male); " EDU" is a dummy variable ( illiteracy=1; elementary school=2; middle school=3; high school=4; and above high school=5); and "ATP" represents the attitudes towards current water prices (zero if reasonable, one if not reasonable). This paper uses two continuous variables: "SC" is given by the social capital score which was calculated using factor analysis from four dimensions of thirty five variables (Miao et al., 2012), and "EFF" is the efficiency score provided by the DEA model.

## 5. Empirical Results

5.1. Efficiency Comparison

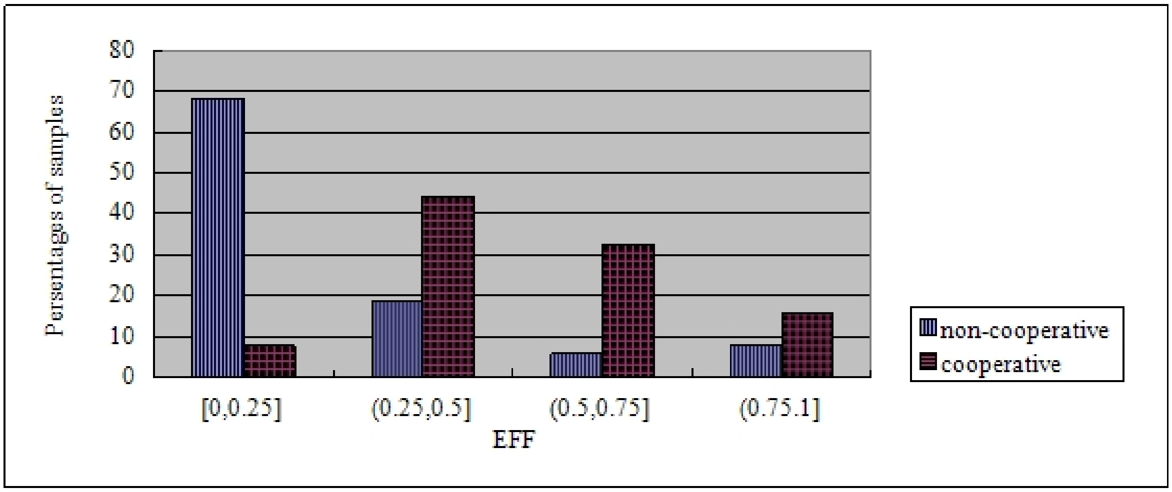



Figure 3. Comparison of Cooperative and Non-cooperative Efficiency

Figure 3 contains an assessment of the number of DMUs that fall into four efficiency categories. Based on the DEA results, efficiency is low, with the average of all the respondents equaling to 0.43. This indicates that there exists a large potential for farmers to improve efficiency and water-use methods (Gerardo and Vincent, 2012). The average efficiency of farmers participating in cooperatives is 0.53, which is 0.29 higher than that of farmers who do not participate in cooperatives (0.24). The majority of farmers' efficiency for the group that does not participate in a cooperative is below 0.25 (Figure 3), indicating that the efficiency of farmer households who cooperate is higher than those who do not. To some extent, the cooperative can improve efficiency by reducing pumping costs (Megumi et al., 2002) and coordination costs. Our results illustrate that non-cooperatives are inefficient, which are similar with Kanbur's (1992) conclusion. Cooperative solutions to ameliorate externalities may be Pareto superior compared to non-cooperative abatement strategies (Loehman and Dinar, 2009). Thus we may reject null hypothesis H1.

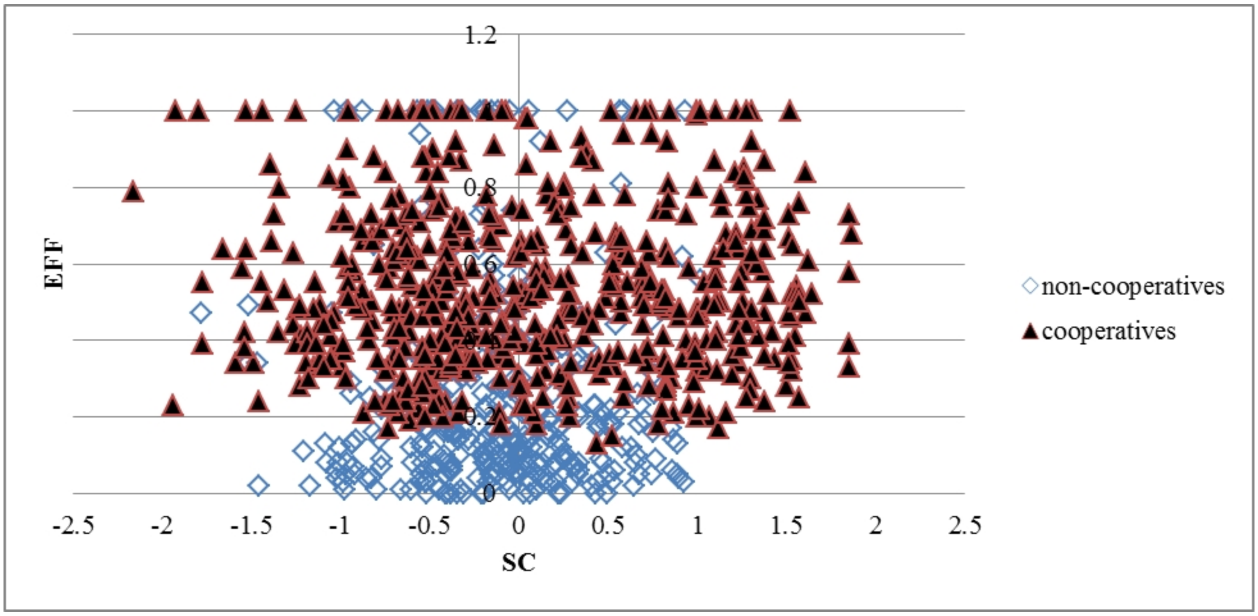



Figure 4. Distribution of Cooperative and Non-cooperative Social Capital and Efficiency

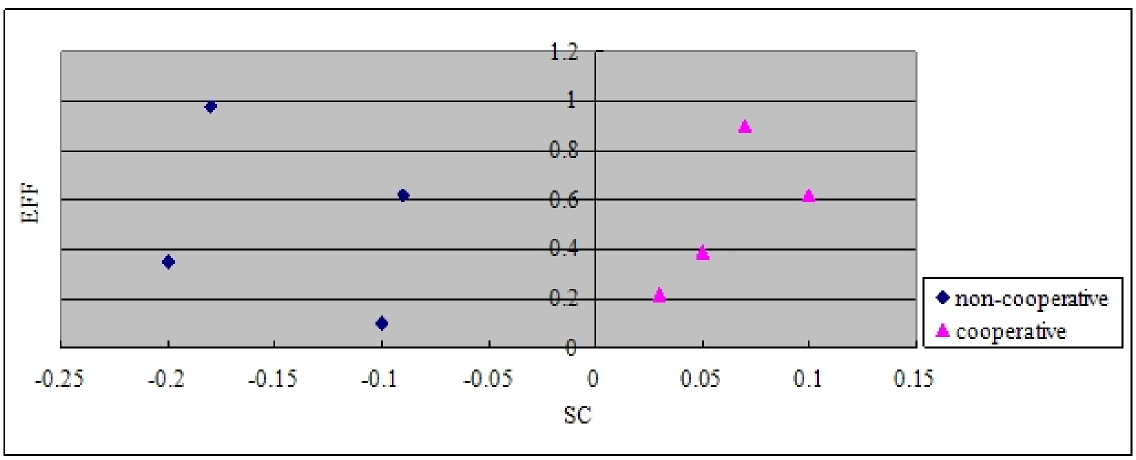
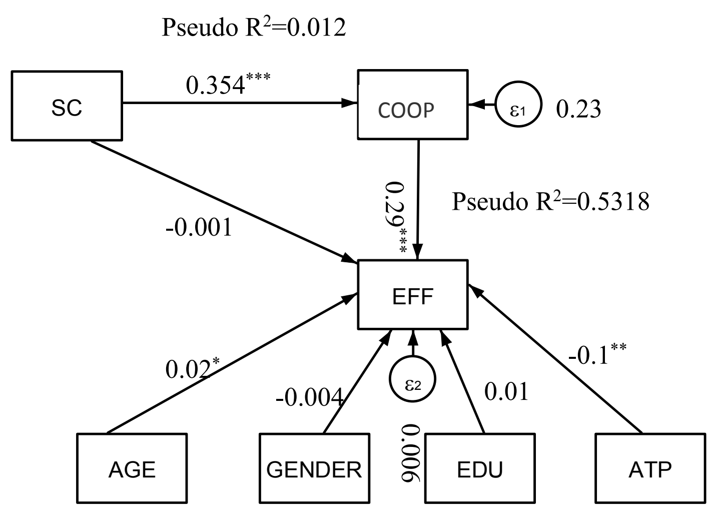



Figure 5. Distribution of Cooperative and Non-cooperative Social Capital and Efficiency with Data Expressed in Quartiles.

Figure 4 illustrates the relationship between social capital and efficiency by separating the groups. After classification of efficiency into two groups, figure 5 shows the distribution of cooperative and non-cooperatives broken down into quartiles. Generally, the relationship between social capital and efficiency of cooperatives is rising. This finding, however, provides insufficient evidence for rejection of H2, and further study needs to be done.

5.2. Determinants of Efficiency




Note: "*""**""***" is 10%, 5% and 1% level. $\chi^2$ =89.92, P value=0.000.

Figure 6. Path Analysis Results

Figure 6 presents the results of path analysis by pooled samples. P value is significant and pseudo $R^2$ has passed the test, which reveals a well-fitting model. Technical efficiency is affected presumably by "COOP", "AGE", "GENDER", "EDU", "ATP", and "SC". In a path model, "COOP" has the largest significant and direct impact on efficiency. The coefficient on cooperative participation is 0.29. Based on this result, we reject H1 and conclude that participating in cooperatives increases efficiency and is necessary to achieve more efficient water allocation and irrigation usage. This result is similar to the conclusions of Uphoff and Widjayaratna (2000). Cooperatives, to some extent, place farmers in relationships with others, which has the benefit of establishing trust and decreasing the transactions and monitoring costs. Additionally, a cooperative supply can provide a mechanism to assure appropriate allocation of scarce water under some institutional arrangements (Parrachino et al., 2006).

As Figure 6 shows, "SC" does not have a direct effect on efficiency in this model as indicated by the insignificance of its coefficient (-0.001). However, social capital (its coefficient is 0.354) does show a significant impact (at 1% level) on the propensity to join a cooperative, indicating that social capital's effect on efficiency is mediated via cooperative. Social capital has been shown to play an important role in the development and operation of cooperatives among farmer households (Dasgupta and Serageldin, 2000; Upoff and Wijayatratna, 2000; Bowles and Gintis 2002; Ostrom, 2007) and following this path, cooperatives will improve efficiency.

In this paper, social capital is comprised of social networks, social trust, social reputation, and social participation. Every dimension of social capital plays a disparate role in cooperative participation. In reality, all the farmers operate under conditions of asymmetries of information (Hayek, 1945). Thus, the cost of searching information for social exchange is expensive. Relying on personal relationships (what we call a social network), is a good way to obtain more information regarding irrigation systems thus decreasing the information seeking costs (Coleman 1988; Fafchamps and Minten, 1999).

Social networks also foster incentives of collecting action towards common goods (Pretty, 2003), especially small-scale irrigation, which improves efficiency by reducing the costs and increasing the mobile resources. Based on this kind of relationship and kinship, farmers involved in such social networks find it much easier to deal with each other (Taylor, 2000; Fafchamps, 2002) and foster trust, namely social trust. Social trust in turn reduces the cost of coordinating irrigation construction as well as reducing conflicts and resulting in more efficient outcomes (Tatlonghari, 2006; Fafchamps, 2006). At the same time, a farmer's reputation comes from, in part, frequent communication and exchange. This communication can be capable of convincing other farmers to voluntarily contribute to irrigation systems thus reducing the problem of free-riders (North, 1973, 2001; Fafchamps, 2006) in the construction and usage of irrigation systems, to some extent which improves cooperative efficiency. Social participation, in a disciplined and trustworthy manner, makes farmers explain their opinions with their preferences about irrigation issues, which promotes interaction with information and trust levels. Social capital facilitates more exchange and communication, consequently creating positive externalities, such as more profits and more incentives to make agreements.

As expected, technical efficiency is positively affected by participation in a cooperative and by social capital, and the effect of social capital is indirect, which leads to rejection of hypothesis of H1 and H2.

In our model, technical efficiency is affected by social-economic characteristics, such as “AGE” and “ATP”. Age has a positive and significant impact on technical efficiency, illuminating that older farmers score higher in efficiency. This indicates that experience with irrigation and therefore the learning processes leads to high efficiency. Attitude toward water prices is negative and significant in the model, indicating an inverse relationship. While this result may seem intuitive, an unreasonable water price will result in there being less incentive for farmers to privately invest in irrigation technology and add additional costs (Fang, 2011).

## 6. Conclusions

In this paper, we classify the supply management as being either cooperative or non-cooperative based on whether the farmers participate in cooperative irrigation systems and propose two hypotheses: “cooperative will not increase technical efficiency of irrigation” and “social capital cannot increase efficiency”. In order to reject null hypotheses, we then calculate the efficiency of each of these two groups. Using those efficiency scores we estimate the factors influencing efficiency using the case of Northwestern China and also estimate the different effects of path in efficiency. The results illustrate that efficiency is diverse between cooperative and non-cooperative settings. To a certain extent, a cooperative setting is able to directly bring higher technical efficiency. The results demonstrate that cooperatives can increase efficiency.

As highlighted in previous research, social capital plays an important role in a cooperative, which indirectly effects technical efficiency. Contextually, social capital is a substitute for government institutional instruments (Grootaert and Narayan, 2004).The results conclude that different dimensions of social capital reduce the costs of time and effort in establishing irrigation systems, which yields higher incentives to participate in a cooperative, as well as higher technical efficiency.

Empirical results lead us to conclude that irrigation cooperatives significantly increase irrigation efficiency in Northwestern China. While social capital does not directly influence irrigation efficiency, social capital does significantly influence participation in irrigation cooperatives and thereby indirectly contributes to irrigation efficiency. It is, therefore, critical to understand the relationship among social capital heterogeneity, cooperative agreements, and technical efficiency of irrigation for policy makers and decision making farmers to regulate and manage water resources, especially irrigation systems. Other socio-economic factors such as age and attitudes toward water prices also have significant effects on efficiency. Findings indicate that triggering farmers to participate in cooperative agreements and cultivating social capital could be cost-effective ways to increase efficiency.

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