CA Discussion Paper 6

China's Water Pricing Reforms for Irrigation: Effectiveness and Impact

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Comprehensive Assessment of Water Management in Agriculture
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Contents

Acronyms

ET	Evapotranspiration
HRS	Household Responsibility Systems
ID	Irrigation District
IDE	Irrigation Delivery Efficiency
JHQID	Jinghuiqu Irrigation District
MOA	Ministry of Agriculture
MWR	Ministry of Water Resources
O&M	Operation & Maintenance
OLS	Ordinary Least Squares
SJID	Shijin Irrigation District
WDID	Wudu Irrigation District
WSC	Water Supply Corporation
WTO	World Trade Organization
WUA	Water User Association
WUG	Water User Group

Abstract

Irrigation occupies a central position in China's crop production. However, due to low per capita water resources, much worse, unevenly distributed over regions and time and the rapid increase of water diversions to non-irrigation sectors, irrigation water shortages have become a very serious problem. Without the adoption of effective measures this problem may even threaten China's food security. Currently, irrigation efficiency is very low in general, irrigation water prices cannot fully recover water supply costs, and irrigation facilities are aging due to the lack of funding for O&M (operation & maintenance). Since water prices are regulated by the government, and not determined by the market, water prices did not work effectively in water allocation. The adoption of more economic incentive measures, such as increasing water prices, has become the main strategy of the Chinese government. Since 1 January 2004, China has carried out a new water pricing regulation. The main objectives of this regulation are that water price should be increased to fully recover water supply cost and that water should be treated as a market good. In non-irrigation sectors, the consensus is that water price could be charged to fully recover water supply cost. However, there is still controversy over the charge of irrigation water pricing. Indeed, increasing water price to fully recover supply cost may seriously affect grain production, and farmers' income. Past studies in China on these issues mainly focused on the theoretical aspects of the problem, analyzing whether irrigation water price should be increased or not. Little studies have quantified the potential impact of the reforms in China. The following questions need to be elaborated:

- Are irrigation water pricing reforms effective?
- What are the attitudes of the farmers towards the reforms?
- How do farmers respond to water pricing reforms?
- What comprehensive methods should be adopted to achieve the goals of the reforms?

This project is based on the analysis of three case studies (Wudu, Jinghuiqu, and Shijin irrigation districts). Jinghuiqu is located in an arid region, Shijin is located in a semi-arid region and Wudu is located in the more humid Southwest. All the issues mentioned above, have been studied using econometric methods on the basis of the data gathered at the household, field canal, pump, and village level. The study reveals that the farmers' ability to pay for irrigation water is still low and that the current water prices reflect the farmers' willingness to pay, which implies that it is in fact very difficult to increase water prices further, let alone fully recover water supply cost. Farmers do not really participate in the irrigation management process, even at the field canal level, which limits the farmers' willingness to pay. In areas confronted with severe water shortages, such as in the Jinghuiqu and Shijin irrigation districts, it is estimated that the volume of water use significantly affects wheat and maize yields, and the reduction of field water use will lead to the decline of grain production. In such cases, although increasing irrigation water price will encourage farmers to reduce water use, it may also force them to decrease their grain production. These measures affect the farmers' revenues, which are largely dependent on crop production, thus increasing social inequities.

Other policies need to protect weaker groups, such as poor farmers and farmers whose income mainly depends on crops. For instance, water property has still not been initialized and both irrigation bureaus and farmers lack incentives to adopt water-saving technologies. Initiating water property, expanding low-cost water-saving technologies, reforming irrigation management and fostering a water market are all important measures to achieve the policy goals of water-saving. At this point, it is necessary to emphasize that surface water price reforms may deeply affect groundwater resources use, especially in the conjunctive irrigation areas. Without the enhancement of groundwater resources management, saving surface water may lead to more overexploitation of groundwater resources, such was the case in the Jinghuiqu and Shijin irrigation districts.

All in all, irrigation water price reforms represent a revolution when compared with traditional irrigation water resource management in China. Comprehensive and integrated policies should be carried out. China being such a large country, reforms cannot be uniform in all areas. Different areas, with different precipitation levels, should adopt different measures. In most parts of South China, volumetric water pricing is not appropriate, since this method requires large infrastructure investments. Collecting water fees on the basis of the farmers' irrigated area is an alternative policy, although it requires involving farmers in the irrigation management process. Even in the northern regions, the standards of irrigation infrastructure should not be overemphasized and more attention should be paid to the cost-benefits analysis of irrigation investments.

CHAPTER 1

INTRODUCTION

1.1 Background

Ensuring food and water security is one of China's basic strategic goals. Rapid increase of water diversions in the non-agricultural sectors is threatening irrigation in China. If no effective measures are adopted, this crisis may have negative effects on China's food security and on the world grain market (Brown and Halweil 1998; Brown 2000). By 2020, the Chinese government plans to further expand irrigated areas to 60 million hectares (ha) from around 57 million hectares in 2004, in order to increase gain production. However, irrigation water needed to further increase irrigated areas must come from the improvement of irrigation efficiency through the adoption of water-saving technology which is the only choice to obtain this goal (MWR 2000).

Currently, Irrigation Delivery Efficiency (IDE) is very low. Irrigation water productivity in China is just about 0.8 kg/m^3. In some developed countries, such as in Israel or the United States, it almost reaches 2 kg/m^3. IDE is estimated at about 0.6-0.7 and 0.3-0.4 for ground and surface irrigated areas, respectively. The MWR is making all efforts to improve IDE to 0.5 in 2010 and 0.54 in 2015 through the adoption of all kinds of water-saving technologies (MWR 2000). Water-saving technology research has achieved much progress in the past twenty years, but expansion is not ideal, as farmers and IDs (Irrigation Districts) are lacking of incentives to adopt water-saving technologies. The government argues that low water price is the main driving force (MWR 2002, 2003a). Meanwhile, some commentators think that increasing irrigation water price can not only urge farmers to take water as a market good, but also relieve the government's fiscal burden by increasing revenues of the IDs (Wang et al. 2003; Han and Zheng 2004).

In general, water fees were low before 2003. In some areas, water was free of charge until 1978. Since then, water price management has been reformed several times and different areas adopted different water pricing reforms (Liao 2004; Lohmar et al. 2001). According to the pricing index, water prices for irrigation increased very slowly before l997ÿthe year the Chinese government carried out a policy designated as *water industry policy*. Prior to this date, water fees collected were equivalent to one-third of water supply costs. Expenditure for O&M in most IDs exceeded total revenues from water fees. IDs suffered losses of capital, and irrigation facilities were aging seriously (Li et al. 2003). In 1997, the State Council came with *the water industry policy,* which prescribed that the water price of newly-built water conservancy projects should fully recover water supply costs, pay for taxes, repay loans, and obtain some net benefits. Water prices of existing water conservancy projects should be increased in order to fully recover water supply costs within three years. Since then, water prices for irrigation have rapidly increased in some areas. Some leaders in IDs used an old Chinese saying to describe the situation: "*running fast with small steps"*. On 1 January 2004, the Chinese government formally carried out a new regulation on water pricing for water conservancy projects (See annex 1). The objectives of this regulation are to increase water price so as to fully recover supply costs for irrigation, as well as collecting additional taxes and net benefits in non-irrigation sectors.

Raising water prices definitely provides an incentive to stimulate water users to increase water savings. It is generally agreed that price hikes in the domestic and the industrial sectors can allow to recover supply costs (Han and Zheng 2004; Wang et al. 2003). How such policy can be implemented in the irrigation sector still raises controversy (Liao 2004; Jiang 2003; Perry et al. 1997; Dinar 2000). First, water price hikes to fully recover water supply costs has rarely been implemented successfully, neither in developing countries nor in the developed world (De Moor and Calamai 1997). In developed countries, such as the United States, Australia, and Japan, where market economy is well established, water prices for irrigation are still lower than supply costs. Governments there still subsidize their agricultural infrastructure to support agricultural development. Second, irrigation water price soaring may harm agricultural production and food security. Since 1995, China's input costs for agricultural production has increased rapidly. Increases of irrigation costs are estimated to be the major driving force behind the increase of input costs in North China (Liao 2004). On the contrary, grain prices declined during the period from 1995-2002. In some regions, net benefits of grain production are negative. Considering the small size of Chinese farms, input costs are too high, which results in China losing its original comparative advantage. If water prices for irrigation were to rise to fully recover supply costs, which implies that current water prices would be increased two or three times, this would increase agricultural costs significantly, especially in the northern regions. Since China joined the WTO (World Trade Organization), agricultural tariffs continue to decline, foreign agricultural outputs increase their competitiveness and China's grain production faces very serious competition. Third, the development of the national rural economy in China is at a crucial stage. Income gaps between urban and rural citizens, between eastern and western regions, and between rich and poor farmers have become too large. The Jini coefficient was estimated at 0.42 in 2002, which shows serious social inequities. Currently, it is crucial to lighten the farmers' burden, to increase their incomes, to decrease income gaps between rich and poor and to enhance poverty alleviation (Liao 2004).

Some studies show that water price demand is inelastic (Gibbons 1980; de Fraiture and Perry 2002) and that increase of water prices for irrigation will reduce farmers' incomes, especially those whose income largely come from crops. Fourth, many IDs lack volumetric facilities and water property rights are still not clearly defined. In most cases, irrigation district revenues depend on farmers' water use, thus making them reluctant to take water saving measures. Finally, water pricing reforms seem to affect groundwater resources use, so this needs to be studied (Schuck and Green 2003).

Existing studies on China's water pricing reforms for irrigation are qualitative in nature and usually focus on why price should be increased (Wang et al. 2003; Han and Zheng 2004). All these studies do not define how price reforms impact irrigation water use, grain production, and farmers' income, nor do they explain the farmers' attitudes toward the reform, what their responses are, and whether the reforms are effective or not. Therefore, the following questions should be addressed:

- How is water fee collected in the IDs? What kinds of criteria are suitable for irrigation water pricing?
- What is the proportion of irrigation costs in respect to the total input costs?
- What is the farmers' and the water management organizations' attitude towards water pricing reforms?
- How do farmers respond to the reforms? Do they choose to adopt water-saving technologies, reduce irrigation water, adjust crop structure or abandon farming?
- Can the new regulations adopted to support water pricing reforms be successfully implemented? How does this policy affect water use, grain production and farmers' incomes over regions?

1.2 Research Objectives

The overall objective of this project is to assist decision makers with the formulation of water pricing reforms in order to safeguard food security and ensure sustainable water use in China. Therefore, this study seeks to evaluate the impact of the reforms on irrigation water use, grain production and farmers' income.

The specific objectives are as follows:

1) To survey the farmers' and the water officials' attitude toward the reforms, as well as to evaluate the farmer's ability to pay for irrigation water.
2) To estimate the farmers' response to the irrigation water pricing reforms.
3) To identify management models and water fee collection at field canals.
4) To survey the status of groundwater resources management and water fee collection in groundwater irrigated areas.
5) To assess the potential for increasing water prices for irrigation.
6) To formulate practical irrigation policies for irrigation water pricing in China.

1.3 Outputs

The outputs are as follows:

- The primary data collected at the household, field canal, pumping well and village levels.
- A comprehensive assessment of the effectiveness and impact of irrigation water pricing reforms.
- A database with irrigation water requirements, irrigation prices, agricultural inputs, irrigation delivery costs and O&M expenditure at a national and regional level.

1.4 Activities

The following activities are undertaken to produce the above outputs:

- Analysis of material collected from the Ministry of Agriculture (MOA), Ministry of Water Resources (MWR), State Statistical Bureau, and some database in IWHR. Wide consultation with all relevant experts and water officials via workshops.
- Analysis of water pricing methods and management practices used in different irrigation systems with surface water, groundwater and conjunctive use.
- Assessment of the share of water price with the total inputs of agricultural production, before and after the reforms.
- Exploration of farmers' attitude towards water pricing reforms and evaluation of the factors affecting the farmers' response to the reforms.
- Identification of the potential impacts of water price hikes on agricultural production, farmers' incomes and the adoption of water-saving technologies.

- Definition of an action plan to assist in the formulation of a practical and effective water pricing policy for irrigation.

1.5 Methodology

This research rests fundamentally on a survey conducted amongst farmers and water supply organizations to assess their attitudes towards the new water price policy and evaluate its effectiveness. The other research methods used for this project include the compilation of data and the completion of case studies undertaken jointly with China's Irrigation District Association and local administrative agencies. These case studies were synthesized to develop regional and national strategies and to identify policy options.

Three typical irrigation districts (Jinghuiqu, Shijin and Wudu) were selected as case study areas. Jinghuiqu is located in an arid region, Shijin is located in a semi-arid region and Wudu is located in the more humid Southwest. Contingent valuation (World Bank Institute 2002) was used to evaluate the farmers' attitude towards water pricing reforms and to identify the factors simulating the farmers' response. For collecting primary household data, the questionnaire was first pre-tested to evaluate its effectiveness. Feedback from the pre-test was used to revise the questionnaire. The interviews were conducted between the months of March and July 2004. The enumerators involved in this study underwent a training program and were introduced to econometric models. The econometric software STATA was used to analyze the household data.

1.6 Beneficiaries and Impact

Beneficiaries of this project include farmers, professionals focusing on water and food security issues in China, and central and local policymakers. The latter will benefit from the empirical data gathered relating to the effectiveness and the impact of the reforms. The project also enhanced the technical capacities of the researchers involved.

In the long run, this project will contribute to improve water management and water use in China, and increase water productivity through the definition of more effective management policies, which should contribute to increase China's food security, sustainable agriculture growth, and social and economic development.

CHAPTER 2

CHINA'S REFORMS OF IRRIGATION INSTITUTIONS

There are approximately 402 large-sized IDs whose effective irrigation area is greater than 2 million ha, 5,600 medium-sized IDs whose effective irrigation area is between 667-2 million ha, and more than thousands of small IDs. As the irrigation institution arrangement is closely linked with irrigation water pricing reforms, this section briefly presents the ongoing irrigation management and reforms.

2.1 Irrigation institutional arrangements

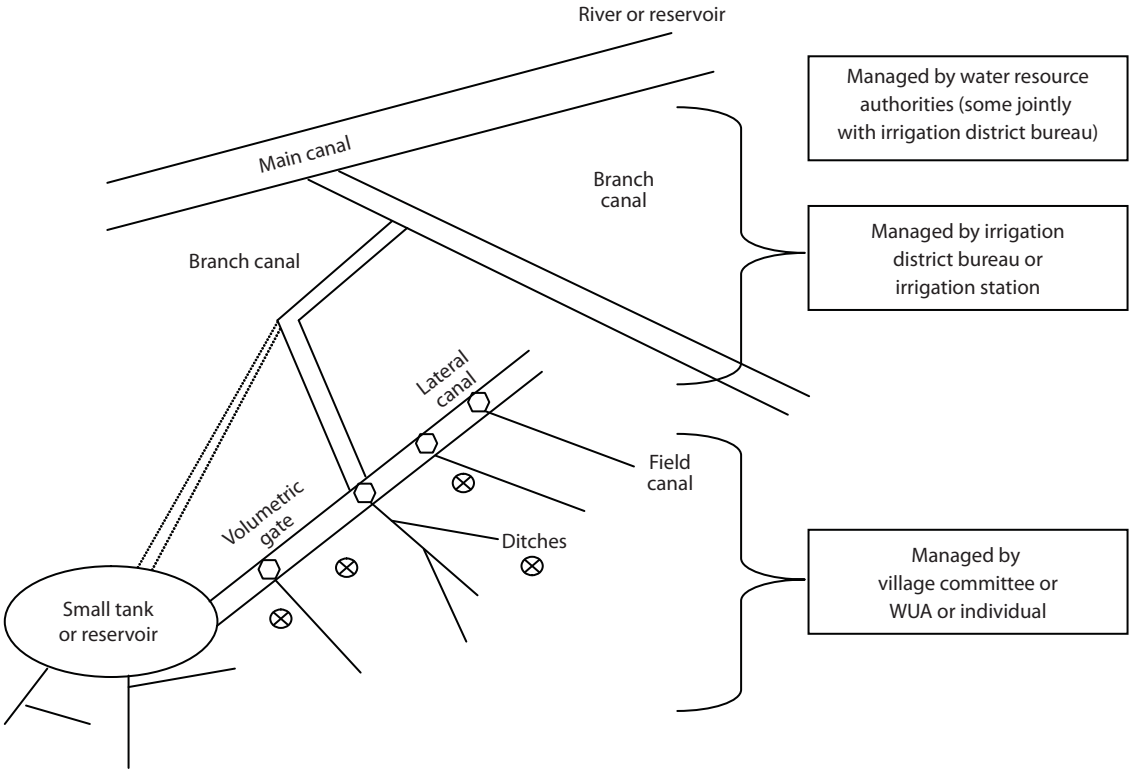
2.1.1 Administrative systems of irrigation

China's irrigation is managed by the water authorities. The Ministry of Water Resources is the highest administrative level of water resources. There is a Department of Irrigation and Drainage Management at the MWR, whose roles are irrigation macro-management and irrigation industry instructions. There are seven river basin commissions set up in the Yangtze, Yellow River, Huaihe, Songliaohe, Haihe, Pearls and Tai Lake. The river basin commission is the overall basin water resources regulator/planner. The provincial water bureau plays a dual role: water regulator/planner and water operator/planner. The duties of the water resources bureau at the provincial level include planning, survey, design, construction, operation and management of irrigation, drainage, flood control works and rural hydropower. The water resources bureau at the prefecture and county level is directly responsible for constructing and maintaining irrigation infrastructure, associated irrigation and flood control facilities and medium-sized reservoirs. The irrigation stations at township level share responsibility for constructing and maintaining branch and lateral canals, ancillary works and small reservoirs, and collecting water fees. The staffs in the prefecture and county bureaus and township irrigation stations, are organized into irrigation district management authorities. And field canals are generally managed by village members. Different irrigation areas differentiate financial management rules.

Figure 1 outlines the administrative and finance arrangements of the current large sized-irrigation districts. Water pumped or gravitated from the head of the main canal, enters into the canal system flowing to farmers' field cropland through main canal, branch canal, lateral canal, field canal and ditches on a broad generalization. However, in the irrigation districts in the south of China, water from the lateral canal usually enters into small reservoirs or tanks before farmers pump it for irrigation. The water flow from the head of the canal is not only a process of physical water flowing, but also a process of money flowing. A rational money flow and physical water flowing as well, can guarantee sustainable water use and normal operation of irrigation facilities.

Currently, most of the large-sized irrigation areas adopt a management method of integrated professionals and farmers' participation. The governments set up specially assigned organizations such as the irrigation district bureau, whose responsibilities include the management of water conservancy projects of main canal and water distributions. The field canal committee or leaders, organized by the benefited farmers, manage the field canals. The irrigation districts direct the sub-sectors' management. Small irrigation districts are generally managed by collectives of village farmers.

Figure 1. A conceptual model of an irrigation canal system and management in China.



The irrigation district agency, as a professional irrigation management organization, has multi-disciplinary irrigation professionals such as engineers, technicians, accountants, and administrative staff. There is one director and several vice directors in an ID. One ID's bureau sets up several divisions such as project management division, irrigation division, financial division and multi-industry division. The salaries of these staff come from the water fees collected. Sometimes, the governments subsidize the irrigation districts on facility maintenance. The managers at the field canal get certain marginal benefits from higher management organizations, and the local township government in irrigation seasons. There is a representative congress in a large-sized irrigation district whose members are voted after consulting many interest groups. The congress includes water user representatives, irrigation bureau representatives, local government representatives and other representatives. The congress is taken as the highest power organization of the irrigation district. The congress holds, at least, one meeting to hear reports of the irrigation bureau and censor the long-term development program, yearly development planning, and yearly budget planning of the ID. The congress determines the management committees, the executive organization representing the congress to manage the ID.

2.1.2 Current challenges of the irrigation management

- Water fee collected cannot recover water supply costs, and irrigation facilities aged cannot be normally maintained.
- Water fee collected was often embezzled, which should be expended on irrigation facilities rehabilitation.
- Water is charged at a flat rate on the basis of land areas in these irrigation districts without volumetric facilities. This weakens the farmers' enthusiasm of adopting water-saving technology and water fee submission.
- Farmers' participation in the irrigation management is not sufficient.
- The absent definition of water rights is a significant cause for the lack of incentive for water conservation.
- The absence of effective mechanisms to control the quantities of water-drawn permits and overexploitation of groundwater resources.

2.2 The ongoing reforms of irrigation institutions

2.2.1 The overall objectives of the reforms

The general office of the State Council issued a rule, known as *reforms and implementation of institution of water conservancy projects*, which prescribes the overall objectives of irrigation management reforms. That is, the establishment of management systems and operational mechanisms for water conservancy projects under China's specific social and water conditions, on the principles of clear definition of rights and duties, standardization of management, multiple sources of investment, market-orientation, and service-socialization. The overall objectives are as follows:

- Establishment of effective management systems of water conservancy projects in which duties and rights are clearly defined.
- Establishment of effective operational mechanisms of water conservancy projects, of which administration is scientific and management is standardized.
- Establishment of effective maintenance systems of water conservancy projects through market-base, specialization and socialization.
- Establishment of rational water pricing mechanism of formulation.
- Establishment of standardized rules of capital investment, utilization, management and monitor of irrigation.
- Establishment of perfect policy and law system.

The specific objectives of the irrigation management system are as follows:

- Development of multi-industry to increase the total revenues and reduce the total employees, who are engaged in the irrigation for reducing salary cost of irrigation water supply.
- Gradually increasing water fee on the prerequisites of lowering water supply costs through enhancing internal administration for solving the problem of continuing capital loss.

- Defining enforceable property of water conservancy projects.
- Defining the rights and duties of specially assigned managerial organizations and mass organizations.
- Encouragement of extensive farmers' participation in irrigation management, such as the establishment of Water User Associations (WUAs).

2.2.2 The evolution of irrigation management reforms

The old management paradigm of water resources were set up under the planning economy in the past decades. Water fee collected from water users was too low to provide incentive signals for effective allocation of limited water resources. The water pricing mechanisms failed to adjust water supply and demand, which intensifies water stress. Water conservancy projects cannot effectively operate due to lack of normal maintenance. The general tendencies of water resources management reforms are to integrate water resources management, to enhance the roles of water prices and market mechanism in water allocation among different users. Irrigation management institutions should be comprehensively reformed in various ways of management philosophy, management structure, irrigation investment methods, water rights, prices and markets.

Currently, the reform orientations and main policies of irrigation management in China may be briefly summarized as follows:

Changing supply management into demand management. The past paradigm is a supply management. The prominent characteristic of this paradigm is to meet the increasing water requirements of different sectors through building large or medium-sized water conservancy projects. This paradigm played an important role in solving the inequilibrium problem of water supply and demand. However, it is unrealistic to increase additional water conservancy projects as in the past because the water development ratio and costs are higher and higher. The overexploitations of water resources lead to serious environmental and ecological problems. That is the reason for using demand management, which means to manage water resources by a combination of market forces, government directions, appropriate institutions and policies and strict laws to limit excessive increasing water demand. This paradigm of demand management focuses on rational water allocation and water saving by effective water management, rather than increasing more water supply capacities by building additional water conservancy projects.

Reducing excessive administrative intervention in irrigation management. The state has been the main investor of irrigation infrastructure in the past. The leaders of irrigation districts are determined by the same level government. Their behaviors are usually influenced by the government officials. It is not unusual for government officials to excessively interfere in the daily irrigation management affairs, but the officials do not bear responsibility for all the serious consequences. This is a very important reason for irrigation efficiency still being low. In the future, one crucial policy is to reduce administrative interference.

Encouragement of farmers' participation in irrigation management. China is making her efforts to expand the management paradigm of the self-financing irrigation and drainage irrigation district that the World Bank is diffusing. This paradigm comprises of a Water Supply Corporation (WSC) and Water User Associations (WUAs). The WSC is for management, organization, and maintenance of the main irrigation system and supply of bulk water. The WUAs are established by farmer groups for construction, management, and operation and maintenance of lateral canal and on-farm systems. This is one of the government's strategies to transform irrigation management agencies into self-financing, independent legal entities. This has been piloted in some IDs whose properties of water conservancy projects are comparatively defined and independently operated.

Rationally fix authorized size of irrigation management agencies. The staff is often so many that it is more than the requirements. Water fee collected is not sufficient to expend for salaries in lots of IDs. Then the agencies lack funds for the rehabilitation of irrigation facilities. It is urgent to reduce the staff to decrease the irrational costs of water supply. The water administrative and financial sectors of the State Council jointly work out a regulation known as the *staff standards of the management organization of water conservancy projects* in 2002. Irrigation agencies should rationally set up positions, its duties and qualifications to reduce staff numbers to a rational level. These institutions should be adjusted to meet the requirements of the separation of management and maintenance of water conservancy projects.

Defining enforceable water rights, developing water market agents and reforming water prices. In brief, water resources, both surface water and groundwater, belong to the state. The Water Law has already defined rights and obligations in water issues, but does not define allocation and transfer rights after various organizations obtain water use rights. Water rights are often obtained by some sectors or regions. Without definition of the initial water rights, water markets would not be established successfully and water pricing reforms are deemed to face difficulties. It is not easy to stipulate water-saving incentives for water users. This is especially important for farmers. It is evitable that more and more water resources will be transferred to non-irrigation sectors with the development of the economy. If initial water rights cannot be properly defined, the tremendous benefits of irrigation water rights that belong to farmers will be lost to the non-irrigation sector without fair compensation. Assuming that there are 500-600 billion cubic meters (BCM) of water resources belonging to farmers, in the approximate 800 BCM of potential maximum utilizable water resources, and remaining just about 350 BCM water for irrigation, then about 250-300 BCM water will be shifted from irrigation to non-irrigation when water diversion peaks at the maximum. Assuming 0.2 Yuan per CM, the value of shifted water resources equals to 30-40 billion Yuan, which is equivalent to total government subsidies to agriculture in 2004.. Irrigation sectors can use the benefits from selling water rights to develop and expand water-saving technologies (Liao 2004).

CHAPTER 3

OVERVIEW OF IRRIGATION WATER PRICING REFORMS

This chapter presents the origins of water pricing reforms in China, defines water pricing policies, as they were carried out recently, and surveys the progress made in some typical irrigation districts. The purpose of this chapter is to provide a backdrop on the ongoing irrigation water pricing reforms in China.

3.1 The evolvement of water pricing reforms

Before 1978, water was usually considered as a free good throughout China. As the main investor, the state controlled all of the water supply. In general, the government invested capital and the farmers provided the labor forces to build irrigation facilities. From 1949 to 1965, irrigated areas drastically expanded from 11.2 million ha. to 33.6 million ha through the government's political movements. Although a regulation prescribed that water supply organizations could collect water fees from water users, this rule was rarely implemented in practice, partly due to the Cultural Revolution Movement. In the late 1970s, irrigation delivery efficiency was just about 0.3, while irrigated areas kept expanding. Water fees were very low relevant to supply costs.

In the early 1980s, the State Council carried out a policy requiring that water supply organizations should be treated as enterprises, in order to reflect the country's move towards building a market-economy. The State Council also issued a regulation on Water Fee Accounting, Collection and management for water conservancy Projects (WFACP*).* This regulation was implemented until a new rule was issued in 1997. The main items of the WFACP were:

- Water fees should be managed as operational fees. Water supply organizations should be considered as an institutional entity (there are three types of organizations in China: governments, institutions and companies). Operational fees should be managed by the fiscal department.
- Water supply costs should be rationally accounted for.
- Water fee standards should be adapted to associated regions and sectors.

Before 1997, irrigation water prices increased slowly. By 1985, the establishment of Household Responsibility Systems (HRS) was almost completed throughout China. Following this reform, each household's plot size became very small, especially in South China. From 1985 to 1992, the governments largely reduced its investments in the irrigation sector because they focus on the development of non-agricultural sectors. Irrigated areas were stagnant and irrigation efficiency remained low. After 1990, water resources began to shift from the irrigation to the domestic and industrial sectors. China's irrigation enters a water shortage era. In addition, the financial status of most IDs became problematic. Most IDs lacked the funds to undertake the O & M of irrigation facilities. The necessity for taking water as a market good, rather than a public good, gradually became urgent. In 1997, the State Council issued the *water industry policy,* which prescribed that water prices for newly-built water conservancy projects should fully recover water supply costs, taxes, and loans. For existing water conservancy projects, the policy stated that water prices should be increased to fully recover water supply costs within three years. Since then, water prices for

irrigation hiked in many areas. In 2001, the state planning commission, the MWR and the MOA jointly issued a rule entitled *comments on the reforms of agricultural water pricing,* which highlights the potential impact of the reforms on irrigation water use, agricultural production and farmers' income. The rule pointed out that water pricing reforms should pay more attention to the farmers' ability to pay for irrigation. On 1 January 2004, the Chinese government formally carried out the new water pricing regulation for water conservancy projects (Annex 1).

3.2 Irrigation management and water pricing reforms in typical irrigation districts[1]

In this section, we analyze the ongoing water pricing and management framework in some typical IDs. The IDs surveyed include: the Yahekou ID in the Henan Province, the Weishan ID in the Shandong Province, the Ganfupingyuan ID in the Jiangxi Province, the Huiting Reservoir ID in the Hubei Province and the Xingdia ID in Gansu Province in the northwest of China.

3.2.1 Yahekou ID

This ID is one of the first large irrigation districts that started experimenting with irrigation management reforms. The total irrigated area in this ID is about 158,700 ha, and the methods used for water accounting and collecting water fees changed drastically over the years.

3.2.1.1Water pricing reforms

- Water fees collected became the main source of revenue for the ID. Prior to 2000, water fees were collected as operational fees and were managed directly by the Department of Finance. The irrigation agency had no right to decide on how to use water fees. However, in 2000, the government's price bureau approved that water fees could be collected and managed by the ID agency.
- Different methods to account for and collect water fees were adopted. Prior to 2001, water fees were collected on the basis of irrigated areas and the volume of water delivered. The basic price for one hectare of irrigated land was about 67.5 Yuan (1 US$ is equivalent to 8.1 Yuan). The water volume was measured at the intake of the main canal. The water price was 0.026 Yuan/m^3. Volumetric water pricing methods varied according to the level of the canal gate. Some volumes were measured at the branch canal level and others at the tertiary canal level. If irrigation water was needed to be pumped from the canal, volumes were measured at the pumps' exiting gate. Volumes of returning water flow were measured similarly at the tertiary canal level. Water fees are now collected to fully recover water supply costs of projects whose funds were originally raised by the government. Water fees for projects managed by WUAs, or being auctioned can be accounted in three components: basic fees, volumetric fees and rent. Water fees for projects managed by the private sector are allowed to be as much as 10 percent higher than for projects managed by irrigation stations.

[1]The original data comes from the local irrigation districts. We collected the documents through the workshop of irrigation management and pricing reforms held by the China Irrigation District Associations in Yunchen, Shanxi Province in Nov 2003. Points in the documents of local IDs do not represent the authors' view. We just want to draw some general conclusions from the documents provided by the local IDs.

- Improve collection methods of water fee to increase collection ratio. Prior to 2001, water fees were collected solely by local governments. Since then, irrigation agency improved and standardized the government's unitary method of water fee collection. Nonetheless, the township government still plays a central role in the water fee collection process. Township governments now have to sign water contracts with the irrigation agency, in which they specify water supply quantities, water fee levels, arbitration in case of violation, and the duties and responsibilities of both sides. WUAs are gradually entrusted with the responsibility of collecting water fees. In fact, the ID bureau just adopted a method of water fee collection that involves the cooperation between three interest groups, comprising of, the leaders of the WUAs, the township government officials and the village and production group leaders. The township officials are responsible for overall coordination. Members of the WUAs are in charge of supplying water to farmers, providing water fee receipts and answering farmers' questions on water fees. The village leaders, for their part, assist the leaders of the WUAs with the collection of water fees.
- In the Yahekou ID, the ID bureau has assigned special personnel to foresee water fee collection. In some parts of the district, the irrigation agency collects water fees through auctions. This method is usually used where field canals have been auctioned. In some other cases, the ID bureau collects water fees from contracted lateral canal committees, the latter being responsible to collect water fees from the farmers. Finally, another important change relates to the fact that ID bureaus do not take anymore agricultural outputs as water fees. Since 2002, the year the government presented its *taxation fee reform*, water fees can only be paid in money. This affects the water fee collection ratio because the previous water fee was charged in the form of grain procurements by the government.
- Enhance financial management to ensure the rational use of water fees. Ideally, the larger portion of water fees should be used for the O&M of irrigation infrastructure. To meet this objective, the ID bureau just worked out a biannual plan on the maintenance and protection of irrigation facilities. According to this plan, the way in which ID bureaus used to spend water fees was changed. The ID bureau now grants sub-sectors some funds, over which they have an exclusive management right. If total expenditure were to exceed total income, the ID bureau would not give the sub-sectors these additional funds. On the contrary, if there were surplus, the sub-sectors would keep these funds.

3.2.1.2 Challenges

- Water fees cover only one-quarter of the water supply costs, which makes some sub-sectors hard to maintain.
- Some township governments are not willing to assist the ID bureaus with water fee collection.
- Since the implementation of the taxation fee reform, water fee collection has become much harder.

3.2.2 Weishan ID

The Weishan ID is located in the downstream part of the Yellow River Basin. It is the fifth largest ID in China. The total effective irrigated area is about 360,000 ha.

3.2.2.1 Irrigation management system

In the Weishan ID, irrigation management is primarily the responsibility of organizations set up at the prefecture and county level, according to the principles of cooperation, integrated leadership, grade-level management, and professional and massive management. Still, there are some organizations set up at lower levels whose members are constituted mainly of village leaders. The prefecture irrigation division, which is managed by the prefecture bureau, is responsible for: 1*)* managing key transboundary projects across several counties, 2) planning irrigation water use and water distribution, and 3) instructing the work of the irrigation sub-sectors. The functions of irrigation agency operating at the county level are similar to those working at a higher level. The executive committee of the ID is comprised of leaders from different sectors of local government. The director of the irrigation committee is the vice director of the prefecture's authority in charge of water management. The vice directors are the directors and vice general secretary of the general office and the chief of the prefecture's irrigation division. Commissioners are chosen amongst leaders of several administrative sectors and the vice presidents of counties benefiting from the water conservancy project. The executive committee is in charge of supervising the irrigation agency, representing the grassroot masses, determining the development and reform strategies for the irrigation districts. The structure of the executive committee at the county level is similar to that at the prefecture level. The grassroot managerial groups are responsible for organizing the farmers who live along the canals, managing the construction of dikes and auxiliary works. Irrigation bureaus define plans for water use, estimate volumetric water supply, and assess water distribution according to the principle of grade-level management. Currently, the agency is making efforts to establish WUAs to manage lateral and on-farm irrigation facilities.

3.2.2.2 Reforms and Water fee collection

Until 1992, water fees were managed as administrative fees through fiscal department of governments. In line with the principle of *running fast with small steps,* the agency had increased irrigation water prices several times. During the period from 1992 to 1997, water fees were increased annually by 0.028 Yuan/m^3, and by 0.04 Yuan/m^3 between 1998 and 2001. In 2002, water prices were raised by 0.05 Yuan/m^3. But, between 1994 and 2002, the total irrigation diversions decreased from 1 BCM to 0.68 BCM. During this period, flat water fees were changed to a volumetric water fee. Water fee standards are determined on the basis of water supply costs. Water fees vary between upstream and downstream canals. The prices also vary according to the different irrigation seasons. Before the peak irrigation season, water fees are discounted. If water demand exceeds the planned quotas, water fees are determined on the basis of a block tariff.

Water fees are collected by and accounted for at various management levels. Proposals from the prefecture and county level related to water fee adjustment should be reported to the prefecture government and the farmer burden-reduction office. Once their proposal is accepted, irrigation organizations must give farmers a notice, known as the farmers bearing production fee receipt. Farmers pay their water fees to the township financial department, which submits all water fees to county financial departments. The county financial departments later redistribute 60 percent of the water fees back to the prefectures and keep the remaining 40 percent. The prefectures' irrigation divisions reward counties who submit their water fees on time by granting them an extra 11.5 percent of water fees or by sometimes granting them additional funds for water conservancy projects.

3.2.2.3 Challenges

- Water accounting methods are irrational and water fees collected cannot recover water supply costs.
- Given the complex authorization process, it is hard to adjust water prices.
- Water fees are managed by financial departments as extra-budgetary funds. Some water fees are transferred to other utilizations and some financial departments hold back part of water fees.
- Due to the lack of volumetric facilities, township stations cannot volumetrically measure irrigation water at household level. Consequently, water fees are usually collected at a flat rate, either on the basis of land area cultivated or on the size of the household. Some farmers are reluctant to pay water fees.

3.2.3 Ganfupingyuan ID

The Ganfupingyuan ID is located in the vicinity of the Nanchangpingyuan city, the capital of the Jiangxi province. Although water conservancy projects were built mainly for irrigation, they also serve other purposes such as flood control, drainage, navigation, electricity generation, other industrial and domestic water use and environmental water supply. The effective irrigated area is about 800,000 ha.

3.2.3.1 Irrigation management system

Irrigation management in the Ganfupingyuan ID is characterized mainly by its combination of both united and grade-level management. Irrigation management organizations spread across three administrative levels. The key agencies include the provincial irrigation bureau, the county irrigation bureaus and the townships' irrigation stations. Provincial and county irrigation agencies are managed by the same level of government. Water management agencies at each level are self-financed entities.

3.2.3.2 Water pricing reforms

Water pricing reforms target, most of all, users in the non-irrigation sectors. Over the years, water prices in the industrial and domestic sectors were increased on numerous occasions. In 2002, water prices in the industrial and domestic sectors were increased by 0.15 and 0.10 Yuan/m^3, respectively. Until recently, irrigation water fees were collected at a flat rate of 477 Yuan/ha, which accounts for nearly 60 percent of water supply costs. Since the adoption of the rural taxation and fee reforms, this method of a flat rate can no longer be applied. Farmers pay their water fees to the township government in the form of procurement of grain once a year in the past. Since China carried out its policy on state-purchase and protective-prices, in 1998, water fees can no longer be paid with grain. This rapidly proved to make the collection of water fees more difficult. During this period, the real collection ratio rarely exceeded 30 percent. Following the central government's adoption of the rural taxation and fee reforms, the irrigated areas to be charged had decreased from 61,000 ha in 2001 to 44,740 ha in 2003.

3.2.3.3 Challenges

- Water prices are too low and are adjusted too slowly.
- Effective irrigated areas decreased drastically as more and more arable land is taken up for construction.
- Due to the lack of maintenance funds, irrigation facilities are deteriorating.

3.2.4. Huiting reservoir Id

This irrigation district is located in the northeast of the Jianghan Plain, in the Hubei province. The effective irrigated area is about 21,000 ha.

3.2.3.1 Water pricing reforms

Prior to 2002, irrigation was managed exclusively by township governments and there existed no special management authority to foresee the maintenance of lateral and lower canals, or to collect water fees at these levels. Each township managed its irrigation facilities within its territory, independently. The water fees collected from the farmers, by the local governments, were often tied to other administrative fees. Although not all villages paid their water fees, all could receive irrigation water. The first WUAs were established in 2002. Since then, the irrigation bureau collects water fees directly from the WUAs. Water volumes are now measured at the intakes of the lateral canal. WUAs are responsible for collecting water fees from villages or farmers. Water prices are estimated at 0.055 Yuan/m^3 in 2002, authorized by the Hubei provincial government.

3.2.4.2 Challenges

- Canal and ancillary works cannot meet the irrigation requirements.
- Extreme variations between upstream and downstream conditions make it difficult to coordinate water users.
- Since the establishment of WUAs, management costs have increased significantly, as the township government is no longer responsible for collecting water fees, measuring water in the main canals, or maintaining the canals themselves. Since the reforms, all the duties have been transmitted to the irrigation management bureaus, which lead to higher management costs.
- Water fees cannot recover water supply costs. It is estimated that 1.5 million Yuan are needed to meet the costs of operation. In 2002, the irrigation bureau was able to collect only 0.15 million Yuan, which accounts for less than 10 percent of the required funds. The main reason behind this deficit relates to the low water fee standards and small amounts of irrigation water diversions, because farmers reduce water use after the reforms.
- The irrigation bureaus were not able to keep their revenue stable as irrigation water requirements were very low in these years of favorable weather.
- There are not enough funds to compensate for the irrigation bureaus' loss of capital.

3.2.5 Xindian ID

The Xindian ID is located in the Gansu province, in the northwest of China. It became fully operational for irrigation in 1984. The total effective irrigated area is estimated at 21,120 ha. The total water pumping capacities are evaluated at 120 million cubic meters. There are 8 pumping stations and the total lift capacity is estimated at 439.75 cubic meters. Water delivery efficiency reaches 68 percent.

3.2.5.1 Irrigation management

The bureau of irrigation management operates under the umbrella of the water resources bureau of the Xindian Prefecture. The bureau is composed of 14 professional sections, 7 irrigation stations, 8 pumping stations, 3 transformer substations, 1 Jianan company and several irrigation experimental stations. The irrigation management bureau has recently started involving farmers with irrigation management below the lateral canals. As a result, 65 WUAs were established at the lateral canal level and 327 Water User Groups (WUGs) were created at the field canal level. These reforms drastically changed the former irrigation management systems as irrigation agencies are now more independent from local governments.

3.2.5.2 Water fee collection

- *Water fees.* Since 1997, water prices have been increased four times, from 0.20 Yuan/m^3 in 1997 to 0.24 Yuan/m^3 in 2000, and to 0.24 Yuan/m^3 in 2002. In these same years, water supply costs increased from 0.33, to 0.37 and 0.41 Yuan/m^3, respectively. Water fees accounted for 60 percent of the total expenditure. It is worth noting that the price of electricity for high-lifting pumps never exceeded 0.04 Yuan/KWH. As it still is today, electricity is heavily subsidized by the government. In 2002, the irrigation district implemented the program*: Additional construction projects for water-saving in large-size irrigation districts.* The effects of this program were not all positive as it led to the depreciation of fixed-capitals and contributed to the inflation of water supply costs as staff wages increased. While the water supply costs in 2002 increased by 6.9 million Yuan, the total fees collected did not increase, but water fees already accounted for about 40 percent of the total material inputs of crop production.
- *Volumetric pricing*. Water fees are now collected on the basis of the volumes of water supplied to the farmers. During the irrigation seasons, the main canal irrigation stations allocate water to each lateral irrigation station. Lateral irrigation stations then supply water to WUAs, which are responsible for allocating water to Water User Groups (WUGs), and then to farmers. In others, to help the farmers keep track of the water supplied to them, irrigation stations prepared a notebook, in which farmers can record irrigation time, water flows, water users and the quantity of water purchased. Each farmer must put their signature to the notebook after water transaction. Then, the leaders of the WUGs publish the notebooks within the villages.

3.2.5.3 Challenges

- Water prices, too low, do not allow to recover water supply costs. Most irrigation management bureaus lack the funds necessary to support the O&M of infrastructure.
- The ID is lacking water volumetric equipment.
- The farmer's ability to pay for water is still very low.

3.2.6 Summary

Some primary conclusions can be drawn from the aforementioned documents provided by local IDs.

- The current level of water prices is not sufficient to recover water supply costs. Most irrigation districts lack the funds necessary to maintain and rehabilitate irrigation facilities. In 2002, water fees accounted for less than 40 percent of total water supply costs in 100 large and medium-size IDs (MWR 2002).
- The collection ratio of water fees is very low. Nationwide, this ratio averages 50-60 percent. The lack of standardized water fee collection practices and the farmers' low ability to pay, explain in most part of this phenomenon.

- Water measurement facilities are insufficient to meet volumetric water pricing objectives, especially in South China.
- Overstaffing amongst water agencies is prevalent. As a result, water supply costs are higher than what they should be.
- The excessive interference of local governments with irrigation management leads to inefficiencies of operation and maintenance.
- Water rights are not clearly defined, which dissuades farmers and irrigation agencies from adopting water-saving technologies.

3.3 The latest water pricing regulations

The latest water pricing regulation has been issued in 2004 (see Annex 2 for the regulation's complete text). The regulation prescribes the items on water fee accounting and management. The following section presents a brief overview of the regulation's content and key points (Han and Zheng 2004).

3.3.1 Content

The regulation has 6 articles. Article 1 describes the general principles and specifies the regulation's criterions, objectives and scope of application. Water pricing mechanisms are also specified in this article. Except that water prices for water conservancy projects built or managed by private sectors can be determined by themselves, water prices for other projects should be determined by a corresponding higher level of government. Water prices consist of water supply production costs, fees, benefits and taxes.

Article 2 prescribes the principles for water price accounting and the collection methods to be adopted. Water prices are accounted on the principles of recovering supply costs, making rational benefits, and fairly sharing the costs amongst various sectors. If a water conservancy project has multiple functions (e.g. generation of hydropower and protection of flood), water supply costs and fees should be shared among the different users. Water conservancy projects are divided into two categories: agricultural and non-agricultural projects. Between the two categories, accounting methods and benefit standards are different. Benefits are determined on the basis of the net capital benefit for water supply.

Article 3 prescribes that water pricing can be designed as a two-part tariff, block or seasonal tariff. Article 4 prescribes management rights. Water prices for water conservancy projects that cover several provincial boundaries are managed directly by the State Council's Price Administrative Bureau. Water prices for water conservancy projects only benefiting one province are managed by the corresponding Provincial Price Administrative Bureau and the Water Resources Bureau. Water prices for small-size water conservancy projects are determined by the county government. Article 5 prescribes the rights, duties and obligations of all pertinent groups. Article 6 consists of the supplementary articles, prescribing that expenditure and water fees should be based on the principles of the relevant financial and accounting regulations issued by the financial and water authorities under the State Council. This article specifies also the methods that should be used to collect water fees for drainage. Moreover, the interpretation rights of the regulation are also prescribed.

3.3.2 Key points

The new regulation, carried out since 2004, is based on the regulation of *WFACP* issued in 1984. According to the new regulation, water should be managed by the state as an economic good, rather than being administrated as an institutional fee. While in the previous regulation, water tariffs were only perceived as compensating services, the new regulation clearly defines water price as a mechanism to support the recovery of supply costs, the generation of rational benefits, and the achievement of higher water quality standards. The main characteristics of the new regulation are that it encourages water agencies to fully recover water supply costs. In addition, it stimulates that management rights should be reallocated amongst various levels of government, according to the territorial characteristics of water conservancy projects.

3.3.3 Accounting for water supply costs

According to the MWR, governments of all levels should define water prices, on the basis of the social production costs associated with supplying water, as it is prescribed in the Price Law. However, the MWR specifies that it is difficult to assess water supply costs as social costs, because water resources are distributed unevenly. Thus, not all water prices can be decided on the basis of social production costs. Doing so, would allow some management bureaus to make large benefits while others would suffer heavy losses. All water prices are, therefore, accounted according to their specific geographic conditions.

The new regulation prescribes that water tariffs should be determined in order to recover water supply costs. For this purpose, the MWR defines the concept of rational cost. Water supply costs refer to all expenses associated with the sustainable and normal production and management of water resources. The objective of focusing on rational cost is to exclude artificial and accidental costs from water prices. Thus, irrational costs caused by unsustainable and abnormal actions, taken by managers, should not be included in the supply costs. However, water resource levies should be included and submitted to water resource administrative sectors by the water management organizations.

The regulation also clarifies the issue of farmers' labor contribution to water conservancy projects. Since most of water conservancy projects were funded by the governments and farmers provided free labor, the method used to account for the farmers' labor costs is crucial to determine water supply costs. While, these labor costs were considered as fixed-capital in some areas, this was not the case everywhere. The new regulation now is that the farmers' contributions should be included in the water supply costs.

According to the MWR interpretation of the new water pricing regulation, it seems clear that the basic objective of the reform is to increase water price, so as to fully recover water supply costs and to relieve the government's fiscal burden. Water supply costs in the new regulation include capital and O&M costs, it is not an economic cost. Another specific objective of the reforms is to expand the water agencies' power over water pricing management.

CHAPTER 4

WATER PRICING REFORMS AND THE FARMERS' ABILITY TO PAY FOR IRRIGATION

This Chapter introduces the basic characteristics of the three surveyed IDs. Then it focuses on the issue of the farmers' ability to pay for irrigation and the farmers' attitude towards the water pricing reforms, to which policymakers pay more attention.

4.1 The basic characteristics of the surveyed irrigation districts

The Wudu irrigation district (WDID) located in the Sichuan province in the southwest of China (the mid-stream of the Yangtze River Basin) represents the water use and irrigation management in the south area, where water resources are comparatively abundant and also represents the prices accounting in the newly built irrigation districts. The Jinghuiqu irrigation district (JHQID) which is located in the Shaanxi province in the northwest of China (the middle-stream of Yellow River Basin) represents the water use and irrigation management in the arid area. The Shijin irrigation district (SJID) that is located in the Hebei province, in the North China Plain, represents the water use and irrigation management in the semi-arid area.

4.1.1 Wudu irrigation district

4.1.1.1 Physical conditions

The Wudu irrigation district, located in the hilly area of the north of the Sichuan province, started to operate in 1998. The current effective irrigation areas approximate to 84,653 ha. The commanded areas include 8 counties in the Mianyang prefecture. The total length of the main, branch and lateral canals is about 1,145.7 km^2. The water sources are the Wudu Reservoir with 0.594 BCM of total storage capacity and 0.355 BCM of effective storage capacity. The total groundwater resources are about 0.3 BCM and the maximum utilizable groundwater resources are about 29 million cm. The average precipitation within the irrigation district is around 1,000 mm and the average runoff is about 2.076 BCM. The maximum utilizable surface water resources within the irrigation district are 0.222 BCM. The total land area is about 6,833 km^2, and the total arable land is about 0.242 million ha. Of the 0.152 million ha of effective irrigation area, 10,000 ha is directly irrigated by water resources of the reservoir. In 1998, the total population in the ID was around 2.97 million, with 2.53 million rural residents, and grain production was about 1.44 million tons. Per capita arable land was about 0.081 ha.

4.1.1.2 Irrigation management system

On the principle of uniform leading and grade-level management by the prefecture government, branches at the lower administrative levels were named as county Wudu irrigation bureaus. Under the county irrigation bureaus, there are irrigation stations at township levels and then water

management groups having several administrators at the village levels. The Wudu irrigation bureau as an institution unifies water resources distribution and is responsible for the maintenance and operation of the main and branch canals, and the tail canals more than 100 mm out of the prefecture or county jurisdictions. Of 600 staff, there are 252 staff in the prefecture bureau and 348 staff in the county bureaus. The prefecture bureau sets up 10 divisions and 14 branches at the county levels and 31 irrigation stations at the township levels. The irrigation district builds a uniform system of long distance dispatch. There are 2 hydrometric stations and 10 precipitation metric stations.

In general, the irrigation project is one of the water conservancy projects that belong to the first category of projects whose objectives are, for the social and public benefits, rather than for private benefits. The main functions of the project are for promoting agricultural outputs, increasing farmers' income and social stability, as defined by the government. Parts of the irrigation infrastructure are built for public benefits, which need financial subsidies. The final objective of the reform of irrigation management systems is to reduce excessive administrative interferences for establishing a self-financed company.

4.1.1.3 Water fee collection and reforms

The irrigation district started with operation in 2000, so no water fee was collected before. The commanded area of the project is converted into a standard area for water fee collection. For instance, total irrigation diversions in 2000 were 448.4 million cubic meters. The standards of water fee in 2000 were calculated as follows:

- In the gravity irrigation area, 1 hectare of paddy land = 1 standard hectare (as a metric criterion of water fee), 2 ha of dryland = 1 standard ha.
- In the lifting irrigation area, 2 ha of paddy land= 1 standard ha. 4 ha of dryland = 2 standard ha.
- Water fee per standard hectare was 495 Yuan (the local authorities estimated that it only accounted for 21.9 percent of the water supply cost of 0.3037 Yuan per cubic meter).

The irrigation bureau theoretically implemented a two-part water tariff, but a flat fee in reality. The base water fee per standard hectare was 420 Yuan, with base water supply of 3,750 m^3 allocated in 4 times. Water supplied during the 1-3rd month, during the 4-6th month, during the 7-9th month and during the 9-12th month is 750 m^3, 1,800 m^3, 60 m^3 and 60 m^3, respectively. Water volumes are measured at the intakes of branch or lateral canals, depending on the specific conditions of irrigation facilities. The irrigation bureaus issued a specific receipt of water fees. The branches of the irrigation management collect water fees and submit them to the prefecture bureau – 50 percent of the total requirements of water fee collection before 31 July of every year and the remaining 50 percent before the end of the year. If the managers of the branches can successfully and timely pay water fees to the headquarters, then they can receive parts of water fees returning from the head. If the county irrigation agencies cannot timely submit water fees to Wudu irrigation agency, the Wudu irrigation agency will punish the branch managers in terms of money. So that even the branch managers cannot timely collect water fees from the township stations, which collect water fees from farmers, and sometimes the branches or township stations pay for farmers in advance and expect to be repaid later.

4.1.2 Jinghuiqu irrigation district

4.1.2.1 Physical conditions

Jinghuiqu, which is located in the GuanZhong Plain in the middle of the Shanxxi province, is a typical irrigation district of conjunctive water use. It is surrounded by the Jing, Wei and Shichuan rivers in the west, south and east, respectively. The Jing River is the water source. The utilizable water resources in 75 percent probability are 0.826 BCM. The average irrigation diversions in 1996-1998 were 0.206 BCM. There are 19,000 pumping wells for irrigation around the irrigation district in 2002. The conjunctive irrigation area is about 733,000 ha. The maximum utilizable groundwater resources are 0.21 BCM, and total diversions are about 0.229 BCM.

Total land areas are 118,000 ha with 91,260 ha arable land. The surface areas of rivers, lakes and small reservoirs are around 3,000 ha. The effective irrigation area is around 83,900 ha, with the gravity irrigation area 74,000 ha, and the lifting irrigation area 9,900 ha. Irrigation area where field water-saving projects have been achieved to standard level was just about 17,667 ha. The irrigation area commanded by drainage projects is about 68,667 ha. Wheat and maize are the main crops. In 1998, the wheat, maize, cotton and other cash crops area were 68,733, 66,533, 48,733, and 98,666 ha, respectively.

4.1.2.2 Irrigation management system

The irrigation district implements the management system of collaborating professions with mass. The irrigation bureau is directly managed by the provincial water resources bureau and sets up 9 divisions, 12 irrigation stations and 5 multi-industry centers. On the principle of irrigation as chief business and diversified management as well, all sub-sectors contract with the bureau with defined duties, self-management, taking responsibility for their surplus or deficits and making production or benefits contract, and routine checking. The irrigation stations carry out the system of overall responsibility by the station leader and workers congress under the leadership of the communist party.

The Jinghuiqu irrigation bureau started with reforms of lateral canal property as the breakthrough of the irrigation management reforms. The previous management systems of most lateral canals had been reformed since the late 1990s. Of 538 lateral canals, there were 428 lateral canals with a contracting system in 2000. There were two types of contract such as, one individual contracting one lateral canal, and several persons jointly contracting one lateral canal. After the contracting reforms, the staff of the irrigation stations reduced by 148 and the irrigation bureau recalled funds around 1.378 million Yuan. The main measures of contracting lateral canals are as follows:

- Auctioning the using right of lateral canals with the minimum price of 2,000 Yuan per km.
- Carrying out the controlling system of maximum water pricing.
- The term of validity was about 10-15 years for the irrigation staff and 15-20 years for other contractors.
- Every contractor had the task of minimum water diversions based on the amounts in the past five years and of increasing farmers' irrigation diversions by 3 percent each year in the future.

- The development right of land along the lateral canal belongs to the corresponding contractor.
- The administrative staffs of each division of the irrigation bureau are associated with several irrigation stations. Their 40 percent salary is closely linked with irrigation diversions of their associated irrigation stations. If irrigation diversions are greater than the minimum amounts required by the bureau, the staff can get marginal benefits. Their salary should be reduced otherwise.

In view of the existing problems in the water allocation, water volume metering, water fee collection and irrigation facility management, the irrigation bureau subsequently issued several regulations such as *the rule of management reforms of lateral canals*, *the detailed rule of making out an invoice for water fee to farmers, the rule of construction funds for lateral canal projects and the rule of water fee expending for the reformed lateral canals.* To standardize the management of the managers of lateral canals, the irrigation bureau made out the measurements of water metering at each farming household level, made out a water fee invoice for each farming household, established records for farming households and delivering water to farming households. The methods of water charging and the required amount for each household should be open to the public in order to ensure the fairness and transparency.

4.1.2.3 Water fee collection and reforms

Jinghuiqu started to collect water fees in 1932, when it started to operate. Water fees had been collected at a flat rate based on irrigation land until 1964. During the period from 1964-1982, a flat rate was only carried out in some areas. At the beginning of the 1980s, the Goods Price Bureau and Water Resources Bureau of the Shanxxi province enhanced water pricing reforms on the principle of *running fast with small steps (increasing water fee slightly but at a high frequency). The* flat water fee was changed into a volumetric fee at the intakes of lateral canals.

Water price was 0.011 Yuan/m^3 in 1982 and an additional 1.5 Yuan per ha of water fee was named as registry fee. It was 0.02 Yuan/m^3 in 1989, 0.062 Yuan/m^3 in 1995 and 0.162 Yuan/m^3 in 2003, wherein 0.10 Yuan/m^3 belonged to the irrigation bureau, 0.032 Yuan/m^3 belonged to irrigation station and 0.03 Yuan/m^3 belonged to the managers of field canals.

4.1.3 Shijin irrigation district

4.1.3.1 Physical conditions

The Shijin irrigation district is located in the Hebei province in the North China Plain. The irrigation district was fully built in 1949 with a command area of 167,000 ha, including the capital of the Hebei province. The conjunctive irrigation district is the largest irrigation district in the Hebei province. The total length of canals at all levels is about 10,800 km with lining canals of 576 km. The Gannan Reservoir and the Huanbizhuan Reservoir are the water sources of the irrigation district. The effective storage capacities of water resources in the two reservoirs are approximate to 1.24 BCM. The average utilizable water resources for irrigation are about 0.44 BCM. The length of main canal whose water flow at the head was designated at 100m3/s is 134.7 km.

4.1.3.2 Irrigation management system

The reservoirs and the irrigation district are separately managed by the Hebei Provincial Water Resources Bureau. The irrigation bureau carries out the management mode which integrates professionals with grassroot masses. The irrigation bureau has independent decisive powers of water allocation, water fee collection and maintenance of irrigation infrastructure.

The irrigation bureau, as a state organization, sets up 7 professional divisions, 10 sub-sectors including 3 water distribution stations, 5 irrigation departments (each department has several irrigation stations), 1 project division and 1 hydropower station. The bureau manages the main canal, secondary branch canals and is responsible for delivering water to the intakes of branches. There is 346 staff in the bureau with 149 technicians. One irrigation station as one organization set up a WUA. Each WUA has several irrigation groups (usually one irrigation group is the same as one village). WUAs (the same as the irrigation station) are responsible for water fee collection according to the water volume of the intakes of lateral canals from the village committees, O&M of lateral canals, and delivering water to the intakes of lateral canals. The village committee collects the water fees from farmers and is responsible for the O&M of field and farm-site canals.

4.1.3.3 Water fee collection and reforms

Water price was 0.004 Yuan/m3 before 1982. During the period from 1983-1990 and 1991-volumetric water fee belongs to the reservoir management bureau, 60 percent belongs to the irrigation bureau and 10 percent belongs to the irrigation stations. The water fee that belongs to the village committee is additionally collected. The amount is generally equivalent to 20-30 percent of the water fees collected by the irrigation bureau.

4.2 The farmers' ability to pay: A theoretical analysis

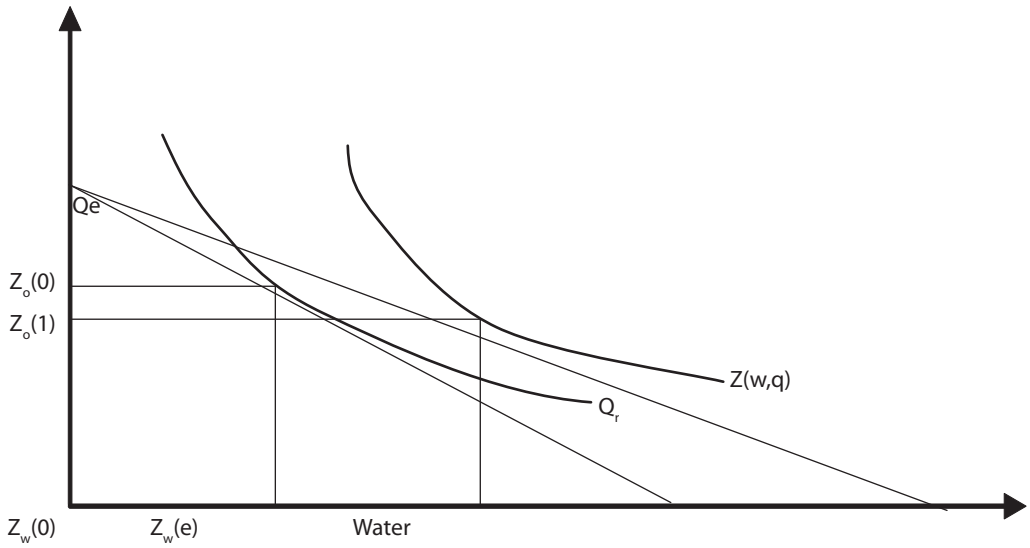
One of the main influential factors of water pricing reforms is the farmers' ability to pay (Liao et al. 2004). However, how to define the concept of the ability to pay is still debatable. Estimating the farmer's ability to pay for irrigation is more difficult. Experts (Wang et al. 2003; Jiang 2003) like to take several indexes such as, the proportions of water fees to the gross benefits, the ratio of water fees over the total inputs, and the ratio of water fees over farmers' revenue to describe the farmers' ability to pay for irrigation.

As a significant input factor, water is used to produce agricultural output by farmers, who make a big effort to capture maximum benefits. The predominating factor that affects the farmers' ability to pay for irrigation is the net benefit of agricultural production. As the farming size of most farmers is too small in China, one of the main objectives of farmers is to produce agricultural outputs for their own consumption. Farmers may choose to produce maximum outputs even in cases where net benefits of planting grains are negative.

Figure 2 illustrates the concept of the farmers' ability to pay for irrigation. Any farmer cannot affect the prices of agricultural outputs in a full competitive market, assuming one farmer needs water and other inputs to produce one agricultural output. $Z_w(0)$ is the amount of water input, associated with water price P^0 and other inputs are at $Z_o(0)$. In this situation, the output of maximizing benefits is $Q_{r,}$ where water amounts are the farmers' willingness to pay. However, if policymakers expect farmers to produce more agricultural outputs Q_e than the quantity farmers are

willing to produce then the irrigation water farmer demand at the Q_e level is $Z_w(e)$ more than $Z_W(0)$. The corresponding water price P^e must be lower than P^0. The difference or ratio between $P^0$and P^e can be used to describe the farmers' ability to pay. The main influential factors on the farmer's ability to pay are the proportions of irrigation cost to the total inputs of agricultural outputs and the net benefits and other physical conditions.

Figure 2. Farmers' ability to pay for irrigation.



More interestingly, we often talk about the concept of the farmer's ability to pay for irrigation, why do not we discuss the farmer's ability to pay for fertilizers, pesticides or seeds? One of the main causes is that water supply for irrigation is a natural monopoly and irrigation water prices are determined by the government rather than water markets. The consumer's ability to pay for market goods are closely linked with the monopoly of water supply.

4.3 Characteristics of surveyed households and cost-benefit analysis of main crops

Questionnaires at the village, household, lateral and irrigation well level are designed in the study. The enumerators surveyed the village leader, the general secretary of the village communist party, the village accountant, the managers of lateral and field canals, the leaders of WUGs, irrigation well managers and three farmers. All questionnaires were protested in March 2004 in the Shijin irrigation districts. The enumerators started a formal survey from May 16 onwards and it was completed on June 14 2004. The total surveyed farming households, villages, lateral canals and irrigation wells were 204, 68, 60 and 58, respectively. The samples allocated in 39 townships of 17 counties were chosen randomly along the main canal of each irrigation district. The surveyed results represent the general situations of the three irrigation districts.

Table 1 presents the basic information of the surveyed farming households. The family members include those who live more than 2 months of one year in the family. Per capita arable land in WDID, the least among the three IDs, is just about 0.08 ha. Per capita taxation and various fees in 2003 were approximately 50 Yuan.

Table 1. Basic information of the surveyed farming households.

ID	Family size	Per capita arable land (Mu)	Taxation and fees per arable land (Yuan/Mu)	Per capita taxation and fees (Yuan)
WDID	3.2	1.2	57.3	69.5
JHQID	4.3	1.5	55.0	83.6
SJID	4.1	2.2	46.6	104.7
Average	3.9	1.8	50.7	89.4

Source: Authors' survey
Notes: One Chinese Mu = 1/15 Ha

The main crops in the three IDs are paddy, wheat, maize, oil seeds and cotton. Table 2 presents the cost-benefit of wheat, maize and paddy in 2003. Taking into account taxation and fee reforms in the following years, the costs exclude tax and fees and the farmer's labor input as well.

Table 2. Cost-benefit, irrigation cost of main cereals. *Unit: Yuan/Mu*

	Net benefit			Cost			Irrigation cost		
	Paddy	Wheat	Maize	Paddy	Wheat	Maize	Paddy	Wheat	Maize
WDID	378.3	187.9	283.2	233.3	121.3	112.6	48.7	0.0	0.0
JHQID	—	241.4	241.6	—	229.7	179.1	—	51.0	32.5
SJID	--	208.6	378.6	—	256.3	116.7	—	52.0	20.6

Source: Authors' survey

Cost-benefit of Wheat. Average net benefit of wheat per Mu in the surveyed fields was just about 222 Yuan in 2003. The highest was in Jinghuiqu, where it was just about 241.4 Yuan and the lowest was in Wudu, where it was lower than 200 Yuan. The average cost of wheat was about 236 Yuan. In Wudu, most of the wheat produced does not need irrigation, and no irrigation fee was included in the costs even when the irrigation bureau still collected the water fee (Maize costs are likewise dealt with). In 2003, irrigation cost per Mu, in Jinghuiqi and Shijin, was 51 and 52 Yuan in 2003, respectively. It averagely accounted for 22 percent of the total material inputs of wheat.

Cost-benefit of Maize. The average net benefit of maize per Mu, in the surveyed fields, even higher than that of wheat, and was just about 311.4 Yuan in 2003. The highest was in Shijin, where it was about 378.6 Yuan and the lowest was in Jinghuiqu, where it was 241.6 Yuan. The average cost of maize was about 144.9Yuan. Irrigation cost per Mu in Jinghuiqu and Shijin was 32.5 and 20.6 Yuan in 2003, respectively. It accounted for some 18 percent of the total material inputs of maize.

Cost-benefit of paddy. Paddy is generally planted in the south of China. Only in Wudu, farmers plant paddy. The average net benefit of paddy per Mu in the surveyed fields, higher than that of wheat and maize, was about 378.3 Yuan in 2003. The average cost of paddy was about 233 Yuan. Irrigation cost per Mu was 48.7 Yuan which accounted for around 21 percent of the total material inputs.

As mentioned above, the average benefits of wheat, maize and paddy per Mu were just about 200-300 Yuan, on the conditions of total costs excluding agricultural tax and other non-production fees, so that policymakers must be cautious of the situation when they desire increasing irrigation water prices.

Further focus on farmers' income. Table 3 presents per capita income of the surveyed households. The average per capita income of the surveyed farming households was between 2,370-3,350 Yuan in 2003. The income from cropping accounted for less than 55 percent. It just accounted for 27.1 percent of income in Jinghuiqu. Although irrigation occupies a central position in food production, it cannot ensure the continuing growth of farmer's income in terms of the structure of income. The impact of water pricing reforms on grain production is worthy of more attention.

Table 3. Per capita income and its structure (%).

ID	Per capita income (Yuan)	Crop	Farm-off	Husbandry	Others
WDID	2,376.2	35.2	24.8	12.6	27.4
JHQID	2,441.2	27.1	48.1	6.0	18.8
SJID	3,351.9	53.1	34.1	1.4	11.4

Source: Authors' survey

4.4 Farmers' attitudes towards the reforms and willingness to respond

To identify the farmers' attitudes towards water pricing reforms and the ability to pay for irrigation, we take the method of Contingent Valuation to design a questionnaire for exploring these issues.

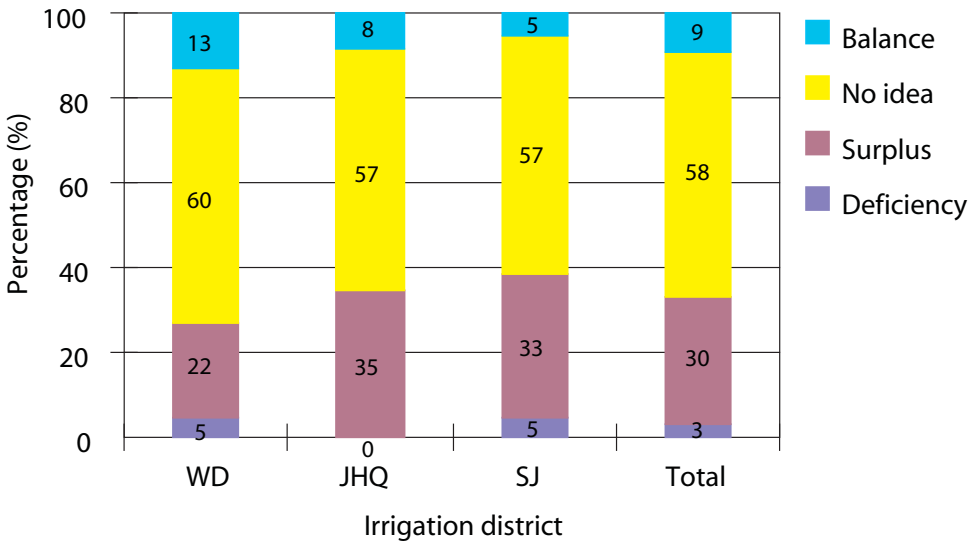
4.4.1 Farmers' attitudes towards the reforms

Several questions are designed to investigate farmers' attitude. The first is, *do you* think whether the current water price is high or not? Of the 180 responders, 36 responders think that it is too high, 65 think it is high, 75 think it is proper and 3 responders think that it is a little low. In the light of these answers, most farmers think that current water prices are at the slightly higher level. As the question is closely linked with the farmer's benefit, the answers may be to some degree deviated. Responders whose answers were 'too high' are further surveyed. When we asked them *how much percentage the current water price is higher than they expect,* the responders whose answers are higher than 10, 20, and 30 percent and greater than 30 percent account for 12, 20, 39 and 29 percent of total responders, respectively.

Farmers' opinions on irrigation water prices imply their ability to pay, but it has not been fully revealed. One responder's answer, to the current water price being too high, does not imply that the farmer cannot pay. When responders are asked, *can you accept the current water prices*, 89 percent of total responders answer that they can accept. However, 15 percent of responders in the Wudu irrigation district think they cannot accept the current water price. The key cause is that some farmers do not need irrigation, but they still have to pay.

A more interesting question is the farmers' attitudes towards water supply management. Responders are asked, *do you think the irrigation bureau gains or loses benefits?*

Figure 3. Farmers' attitudes towards water supply management.



Of 180 responders, only 6 responders, namely, 3 percent think that the irrigation bureau cannot be profitable. In contrast, 30 percent of responders think that the irrigation bureau can gain benefits by irrigation management. The farmers' opinions on irrigation management are totally different from the irrigation authorities, who always complain irrigation water prices are too low to recover supply cost (figure 3).

4.4.2 The highest prices farmers can accept

The methods of water fee collection are different. Wudu collects water fees at a flat rate. Jinghuiqu implements a volumetric water price. Shijin measures volume at the lateral intakes, but farmers in one village submit water fees on the basis of arable land. Different irrigation systems and water fee collection methods differentiate responders' answers to the question of *what is the acceptable highest price*. The average water price for irrigation that the farmer can accept is about 73.4 yuan per Mu in the Wudu irrigation district. However, half of the responders cannot accept it. The standard deviation of the acceptable highest price is about 41 Yuan per Mu, in Wudu. The highest acceptable water price is 24.5 Yuan per Mu, of each irrigation time in Jinghuiqu and it is about 44.2 Yuan per Mu of each irrigation time in Shijin. Table 4 presents the statistical results of the acceptable highest water price for irrigation.

Table 4. The acceptable highest water price for irrigation. *Unit: Yuan*

IDs	Average	Standard deviation	The maximum	The minimum
WDID	73.4	41.38	200	12
JHQID	24.5	6.66	40	13
SJID	44.2	16.84	90	13

Source: Authors' survey. In Wudu it is per Mu. In the others, it is per Mu of each irrigation time.

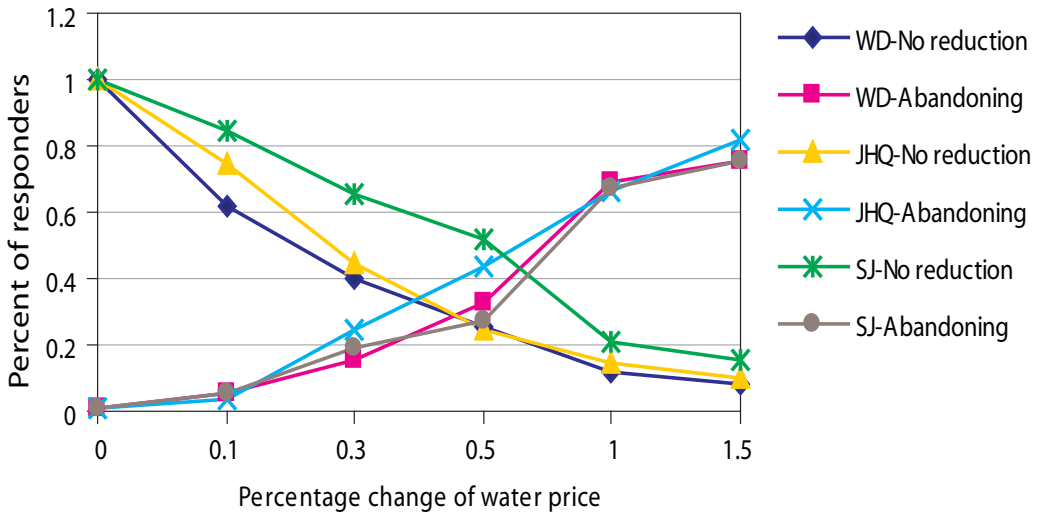
4.5 Farmer's willing responses to water price reforms

There are four types of underlying responsiveness of farmers to surface water price reforms as follows:

- Reducing irrigation times and quantities.
- Using more groundwater resources for the substitution of surface water.
- Changing cropping patterns.
- Adopting water-saving technologies.

We address the above issue sequentially. First, assuming the current water price increases 10, 30, 50 and 150 percent, how much percentage of the current water use are the responders willing to reduce? The change of the percentage of responders, whose responsiveness to the associated change of water prices is willing to reduce water use or to abandon irrigation, to the total surveyed responders are plotted out in Fig. 4. If water price increases by 10 percent, 62 percent responders in Wudu, 75 percent responders in Jinghuiqu and 84 percent responders in Shijin are not willing to reduce water use. In contrast, only 5 percent responders in the three IDs are willing to abandon irrigation. If water price increases by 30 percent, 40 percent of total responders in Wudu, 45 percent in Jinghuiqu and 66 percent in Shijin are not willing to reduce water use, but 16 percent in Wudu, 25 percent in Jinghuiqu and 19 percent in Shijin prefer to abandon irrigation. To continue the questions, if water price increases 50 percent, only 26 percent in Wudu, 25 percent in Jinghuiqu and 28 percent in Shijin choose not to reduce water use. However, 33 percent in Wudu, 43 percent in Jinghuiqu and 52 percent in Shijin prefer to abandon irrigation. If the water price doubles, the responders' behaviors to irrigation changes drastically, and around 80 percent of the total responders choose to abandon irrigation in all the surveyed IDs. Figure 4 illustrates irrigator's response to the change in water price.

Figure 4. Farmer's intensive response to water price.



Second, farmers have an alternative responsiveness for using more groundwater resources if increasing surface water price. Farmers reveal strong preference of the adoption of irrigation pumping wells in the Jinghuiqu and Shijin. Of the total responders without wells, 4 responders in Wudu, 6 responders in Jinghuiqu and 7 responders in Shijin plan to dig wells for irrigation in the coming years. Water price policymakers must consider the substitution relationship between groundwater and surface water. Chapter 8 discusses the groundwater resources institution in length.

Third, farmers may change cropping pattern as a response to the change of water prices. Farmers may change water intensive crop into lower water consumptive crops. We investigate whether the farmer has the willingness to reduce the intensive crop area of paddy in Wudu or wheat in Jinghuiqu and Shijin, given increasing water price. The results show that farmers are willing to reduce the paddy area, given that water fee increases to 60 Yuan per Mu in Wudu. In Shijin, given that water fee increases to 70 Yuan per Mu, farmers are willing to reduce the wheat crop area. However, farmers have no inclinations to reduce the wheat area in Jinghuiqu, even if water price is assumed to increase to more than 100 Yuan per Mu. The main cause may be that farmers can exploit more groundwater resources for irrigation.

Fourth, the results of the farmer's willingness to adopt water-saving technology are very pessimistic. Even if water prices are assumed to double or triple, most of the farmers have no interest to adopt water-saving technology. Most of them think that they cannot gain benefits through investing lots of funds on water-saving technology, such as sprinkle and drip irrigation for wheat or maize. It seems that just the adoption of increasing irrigation water prices is not enough to attain the policy objective of water saving.

CHAPTER 5

PRODUCTION ELASTICITY WITH RESPECT TO IRRIGATION

Grain production elasticity with respect to irrigation is estimated in the form of the Cobb-Douglas function using input-out's data at crop level, further, the marginal effects on grain production of water use is calculated. These parameters of elasticity are also used for the estimation of the potential impact of irrigation water pricing reforms on grain production and irrigator's income.

5.1 Introduction

After China carried out reforming and opening-up policy, grain yield rapidly increased to 4.6 t/ha in 2000 from 2.86 t/ha in 1980. The annual growth rate reached to 2.4 percent in average. Since the growth rate of grain yield has been declining since 1995, commentators began to debate whether China can safeguard food security in the future. Taking time t as an explanatory variable, the increasing trends of grain yields in the past decades can be fitted as logarithmic function curves. The changes of grain yields were mainly driven by technological progress, irrigation investment, input and output prices, agricultural policies as well as the environment.

Economists normally used, the ratio of irrigation area over gross cultivated area or irrigation investment, to explain irrigation's contribution to the growth of grain yield (Huang and Rozelle 1998). In the past decades, although grain yield increased accompanied with the rapid increase of effective irrigation area, no empirical has quantified the positive correlation between irrigation area and grain yield. The growth of irrigation infrastructure only implies the potential guarantee for crop water demand. In fact, irrigation water uses are the direct influencing factor to the increase of crop yields. Observing the change of irrigation diversions in the past 20 years, irrigation water uses have been decreasing rather than increasing. By only making univariate analysis grain yields have negative correlation with irrigation water use. Scientists on irrigation and drainage, use grain yield of unit irrigation water (water productivity) to explain the change of irrigation efficiency or use crop water evapotranspiration (ET) to analyze the relationship between water consumption and crop yield. These studies, based on experimental data, often control other inputs such as fertilizer and seed, etc, which may underestimate marginal technological substitution between irrigation water and other inputs. Few studies use surveyed data to quantify the contributions of water use to grain yield.

To fill this gap, based on surveyed data at plot level, yield production functions of wheat and maize are developed for the estimation of production elasticity with respect to water use at field level.

5.2 Theoretical model and data

According to the crop patterns in the surveyed area and available data, only wheat and maize yield functions are analyzed, in the form of Cobb-Douglas production function:

$$1nY = a_0 + b_1\, 1nx + b_2 lnw + \sum b_i D + \sum b_i D + \sum b_j K$$

Where:

Y refers to wheat or maize yield. X refers to other input vector except field irrigation water, such as fertilizer, seed, labor and labor quality, etc. W refers to field irrigation water, including the ratio of groundwater resources over the total. D refers to regional dummy variables b_1, b_2, b_i and b_j are vectors of parameters to be estimated.

Table 5 highlights the basic statistical characteristics of the samples. Crop patterns in Wudu are wheat-paddy rotation, oilseed-paddy rotation and wheat-maize rotation, which greatly differentiate from these in Jinghuiqu and Shijin in North China, which are mainly wheat-maize rotation. Two plots with different cropping pattern in one household are selected for survey. Observant wheat and maize plots are 270 and 260, respectively, which meets the sample requirements of cross-section data according to large sample theory. The average age of household heads in samples is about 50. Most of the surveyed household heads only have an elementary or junior schooling level, reflecting to some degree that nowadays the qualifications of agricultural labor are very low. There are 4 agrotypes of sand, sand loam, loam and clay soils. Clay soils are predominant in Wudu. In Jinghuiqu, the main agrotypes are loam and clay, however, sand loam soil accounts for major parts in Shijin. Of total observant plots, 4 percent of maize plots, around 17, were damaged by natural disaster. Waterlog was the most serious hazard, which reflects higher uncertainty of maize production. Maize is severely affected by disaster are out of harvest in our sample. Of the three IDs, wheat in Jinghuiqu is the most damaged by drought.

Table 5. Basic characteristics of observed samples.

ID	Plot numbers		Distance between field to home (meter)		Crops area		Average yield	
	wheat	maize	wheat	maize	wheat	maize	wheat	maize
WDID	55	49	436	572	40	35	534	645
JHQID	108	104	534	528	320	316	806	842
SJID	107	106	815	817	351	342	855	973
Total	270	260	625	655	710	693	815	897

Source: *Authors' survey Note: 1 Jin = 0.5 Kg.*

Both yields of wheat and maize in Wudu are the lowest and these in Shijin are the highest. The plot size in Wudu is the smallest among the three IDs. Distance between plots to home is induced into the regression models as an environmental variable of cropping, as distance may impact farmer's investment behaviors.

Explanatory variables such as field irrigation water use are described in detail.

Field irrigation water

When volumetric water price is not used, field irrigation water use is calculated at three levels: village, field canal and crop plot. If farmers do not clearly know actual water use at the plot level, we asked farmers for each irrigation time and volume for each crop. Based on various factors like irrigation duration, irrigation depth, electric power consumption, irrigation expenditure, etc., responders provided the information of actual water use for every irrigation time and estimated the contribution of each irrigation time to grain yield. WDID is located in the south of China, where rainfall can meet crop water requirements on the whole. Although farmers often carry water for supplementary irrigation there when they manure crops, this irrigation water is not surveyed. Little difference of field water use for wheat between Jinghuiqu and Wudu existed according to our survey.

As maize grows in the summer season with plentiful rainfall, field water use for maize as a supplementary irrigation is much lower than that for wheat. Groundwater use in Shijin accounts for large parts of wheat and maize, especially for maize due to the restrictions of poor water conservancy projects. Half of irrigation water used for wheat is from groundwater resources in Shijin. Farmers use more groundwater resources for maize because irrigation volume for individual farmer is so small that the irrigation bureau is not able to supply farmer water timely due to excessively high supplying cost. Because it is more convenient and timely for them to use groundwater for irrigation, farmers prefer to use more groundwater resources. The quality of groundwater may be different from that of surface water. Around 70 percent of responders in the conjunctive irrigation districts of Shijin and Jinghuiqu prefer to use surface water. Most of them think surface water benefits crop more, because the quality of surface water resources are better and the irrigation time of using surface water is shorter than that of using groundwater in the irrigated season of wheat. Thereby, the proportion of groundwater volume over irrigation water volume per Mu is an explanatory variable to hypothesize the difference of grain yield between using groundwater irrigation or surface water for irrigation. Tab1e 6 presents the field water use for wheat and maize.

Table 6. Water volume of field irrigation for wheat and maize.

IDs	Wheat			Maize		
	Irrigation water volume (m^3)	Proportion of groundwater (%)	Proportion of surface water (%)	Irrigation water volume (m^3)	Proportion of groundwater (%)	Proportion of surface water (%)
WDID	0	0	0	0	0	0
JHQID	272	12	88	181	53	47
SJID	255	50	50	95	97	3
Mean	248	31	69	130	68	32

Source: Authors' survey

In the three IDs, field water-saving technologies applied by 194 responders are mainly border irrigation, remaining stubble without tillage for preserving soil entropy, land leveling, drought resistance seed, plastic film covering, deep plowing and furrow irrigation. Most of the farmers apply border irrigation technologies. Field irrigation quotas investigated are higher than that presented by local irrigation experiment stations.

- Fertilizer inputs

Fertilizer inputs are determinant factors of grain yields. Table 7 presents the status of fertilizer inputs. The actual volume of fertilizer used is converted into pure fertilizer volume according to the proportion of nitrogen, phosphor and kalium. Without calculating manure used, the most of average fertilizer used per Mu is in Shijin and the least per Mu is in Wudu, where farmers use amounts of manure. The average numbers of livestock per household in the north IDs are less than these in Wudu, hence farmers in the north IDs manure less on crops. In Shijin, chemical fertilizer input for maize is less than that for wheat. On average, chemical fertilizer input for wheat is more than that for maize, about 25 kilograms. Chemical fertilizer input for maize in the other two IDs is more than that for wheat in Wudu, about 5 kilograms, because maize needs more nitrogenous fertilizer. According to proportions of N, P and K of the total, nitrogenous fertilizer is predominant and other inputs tend to be too low for wheat and maize.

Table 7. Chemical fertilizer inputs for wheat or maize per Mu and respective proportions (%).

	Wheat				Maize			
ID	Chemical fertilizer Input (kg/Mu)	N's proportion	P's proportion	K's proportion	Chemical fertilizer Input (kg/Mu)	N's proportion	P's proportion	K's proportion
WDID	19	58	35	7	25	73	25	2
JHQID	28	52	43	5	32	95	4	1
SJID	39	60	35	5	13	95	3	2
Average	38	57	38	5	22.5	94	5	1

Source: Authors' survey

- Labor inputs

Labor inputs in the processes of grain production are investigated, male and female family labor inputs are separated and exchanging work days, employee work days and work days without payment at every production process are surveyed as well. Thanks to extensively expanding machinery in recent years, labor inputs per Mu have rapidly decreased to a very low level in Shijin and Jinghuiqu. However, the mechanization degree in Wudu is very low, in which labor inputs are by far higher than its counterpart in the other two IDs, reaching 14.65 workdays per Mu. Labor inputs in Shijin are the least, only 2.82 workdays. The situation of machinery and draught animals input fees is just the opposite. The input fees of machinery and draught animals in Shijin reached to 41.17 Yuan per Mu. The counterpart fees in Wudu only reached about 10 Yuan per Mu. In recent years, rotation of plowing machine with sowing, and plowing and fertilizing together has largely been used, which remarkably relieves the farmer's labor intensity. The difference of labor inputs between individual farmers is mainly reflected on plowing and planting. Most of the labor inputs for maize production are about 18 workdays in Wudu, but only 6-7 days in Shijin or Jinghuiqu. Apart from labor inputs for harvest and drying in the sun, labor inputs in both North IDs are less than 4 workdays. Labor inputs in Shijin are not more than 3 workdays. It is worth noting that irrigation water use for wheat or maize in Wudu is assumed to be zero. However, in practice, labor inputs for irrigation are quite a lot, because farmers should carry water to irrigate wheat and maize as supplementary irrigation. Although water use is not too much, irrigation has an effect on crop yield because it provides water at a crucial time of crop water deficit. In addition, labor inputs for weeding in maize fields account for a large proportion. With great variation, these labor inputs are expected to insignificantly impact maize yields. Table 8 presents the details.

- Seeds inputs

We didn't investigate seed breed. Dummy variables of whether seed is bought are used to capture breed diversity. Wheat seed inputs per Mu are about 15 kilograms in average, which is approximate to the national level of 18 kilograms. Seed price in the local seed market is generally about 2 Yuan/kg, the highest reaches 7.5 Yuan/kg, which is far higher than preserved by farmers for planting. Univariate regression analysis shows that there is no remarkable difference of seed inputs between the purchasing and the preserved. Inputs of self-preserved seeds are even lower than that of purchasing seeds. The difference of grain yield due to different seeds' resources in WDID is remarkable, reaching up to 72 kilograms per Mu. In the other two IDs, the difference is not remarkable. In Shijin, the average wheat yield of self-preserving seeds is 21 kilograms higher than

purchased seeds. All observant maize seeds are purchased from the local market, which may be caused by hereditary characteristics of maize.

Table 8. Labor input per Mu of wheat production and maize production (workdays/Mu).

	Wheat			Maize		
Labor inputs	WDID	JHQID	SJID	WDID	JHQID	SJID
The total	14.65	2.92	2.82	17.58	6.86	5.59
Excluding transport and drying	8.47	2.02	2.17	12.29	3.9	2.72
For first fertilizer	1.73	0.38	0.26	1.4	0.33	0.02
For plowing field	1.7	0.27	0.26	1.35	0.1	0.05
For seed	1.98	0.08	0.11	2.29	0.1	0.12
For filling seedling	0.08	0	0.02	0.68	0.32	0.58
For additional fertilizer	0.85	0.13	0.17	2.14	0.86	0.27
For irrigation	0.62	0.31	0.68	1.77	0.36	0.39
For pesticide	1.05	0.33	0.48	0.89	0.27	0.41
For weeding	0.47	0.52	0.19	1.78	1.56	0.89
For harvesting and transporting	3.52	0.21	0.19	2.68	1.46	1.19
For drying	2.66	0.69	0.45	2.61	1.51	1.68

Source: Authors' survey. One workday equals to 10 working hours.

5.3 Estimation and results analysis

Taking into account the influential factors for yield of wheat or maize, the OLS methods are used to estimate the associated parameters for wheat and maize production functions. The estimated results are listed in table 9.

First, look at the variable of field water use. Estimated results of the wheat or maize production function show that the water volume of field irrigation significantly impacts wheat or maize yield at a 5 percent statistical level. Field irrigation water has a significant positive relationship with wheat or maize yield, which implies that irrigation in these regions are insufficient and farmers have effectively used irrigation under current irrigation technologies. Without irrigation technology improvement, the reduction of field irrigation water stimulated by increasing water prices for irrigation would negatively impact wheat or maize yield. The value of production elasticity of field irrigation water for wheat is less than its counterpart of maize, which is consistent, in that, irrigation for maize is supplementary and the irrigation quota is smaller. As for Jinghuiqu and Shijin, if field irrigation water is increased by 100 percent to a certain degree, maize yield would be increased by 4.5 percent and wheat yield would be increased by 3.1 percent at a 95 percent confidential level. Maize yield between surface and groundwater resources are not significantly different. The groundwater proportion of total water use significantly affects wheat yield at a 1 percent confidential level. Estimated results are consistent with the farmers' preference to surface water in terms of water quality. Wheat yield irrigated by surface water is higher than that irrigated by same amounts of groundwater. In Jinghuiqu and Shijin, groundwater volume is too small for normal flow in the field. The irrigation time of using groundwater is too long. The irrigation quality of using groundwater is worse than that of using surface water. In addition, surface water in some regions contains fertilizer and its temperature is higher than that of groundwater. All these factors benefit to wheat production.

Table 9. Estimated results of multiple regression models of wheat and maize production functions.

	Log of wheat and maize yield (Jin OLS)			
	Coefficients		Value of T-test	
	Wheat	Maize	Wheat	Maize
Log of irrigation water volume (m^3/Mu)	0.030**	0.045**	2.37	2.36
Proportion of groundwater	-0.087**	-0.088	-2.24	-0.91
Log of chemical fertilizer input (Kg/Mu)	-0.015	0.073	-0.49	1.27
Log of labor inputs (Workdays/ Mu)	-0.040*	-0.101**	-1.91	-2.43
Education years of household head (Years)	0.013**	-0.014	2.38	-1.2
Ages of household head (Years)	0.001	0.000	0.6	0.44
Log of other inputs (Yuan/Mu)	0.004	-0.001	0.3	-0.36
Distance between plot and home (Meters)	0.003	-0.004	0.98	-0.83
Dummy variable for sand soil (Yes 1, no 0)	0.097	0.000	1.53	0.000
Dummy for soil (Yes 1, no 0)	0.194***	0.083	3.04	0.58
Dummy for clay (Yes 1, no 0)	0.105*	-0.021	1.75	-0.15
Dummy for self-preserving seeds (Yes 1, no 0)	-0.367	-	-1.27	-
Dummy for disaster (Yes 0, no 1)	0.241***	0.006	3.76	0.05
Dummy for Jinghuiqu (Yes 1, no 0)	0.166**	-0.017**	1.95	-0.14
Dummy for Shijin (Yes 1, no 0)	0.289***	0.288**	3.17	2.09
Intercept	5.905***	6.455***	35.88	18.78
Samples	270	253		
Adjusted- R^2	0.490	0.118		

* significant at 10% level, ** significant at 5% level, ***significant at 1% level.

Second, the variable of chemical fertilizer input is analyzed in detail. Since China carried out its reform and opening-up policy, chemical fertilizer inputs have kept up with the growth of grain production. The increase of chemical fertilizer inputs is thought of as being one of the key driving forces behind the increase of grain production. However, estimated results with cross-sectional data show that chemical fertilizer inputs have an insignificant impact on wheat or maize yield, which is surprisingly inconsistent with the estimated results using macro time series data. Maybe chemical fertilizer input is excessively used or the proportion of chemical fertilizer is irrational. Some relevant information shows that in 1998, the gross amounts of nitrogenous fertilizer delivered into the environment, in some kind of way, was around 47.4 million tons and 12.4 million tons were released into surface water. Five million tons were released into groundwater. Thirty million tons were released into the atmosphere, of which 270 thousand tons are in the form of N_2O and 27.3 million tons are in the form of NH_5. Nitrogen results in entrophication of surface water and the nitrate concentration in groundwater. Excessive fertilization use results in groundwater pollution, especially pollution in shallow aquifer. Therefore, it is necessary to train farmers to rationally use fertilization, which not only decreases unnecessary input costs but also reduces environment pollution that resulted from excessive fertilization inputs.

Variable of labor input. A surprise result that labor elasticity is significantly negative comes up not only from univariate factor analysis or multiple regressions, but also from sub-regional multiple regressions. This result is totally opposite to the expectation. By further analysis, we found that dry land whose crop pattern is wheat and paddy rotation need more labor inputs in Wudu. Since grain yield in dryland is low, a dummy variable may be further introduced. In the North of China, labor inputs per Mu are very small, because the degree of specialization and mechanization is increased greatly. Farmers' input labor depending on whether they need to hire workers or not. If farmers hire labor to do these works, labor inputs are small. The negative elasticity of labor input has a correlation to a specialization degree, the variable of the proportion of exchanging labor or a dummy variable of mechanical cultivation could be included in the models too.

Seed variable. All maize seeds are purchased, so no dummy variable is induced in the maize production function. As for wheat seeds, hypothesis testing could be done of yield difference between purchased seeds and self-preserved seeds. Univariate factor analysis shows that whether purchased seeds or self-preserved seeds have no remarkable impact on wheat yield except that in Wudu. There are two possible causes. One possibility is that farmers are good at determining seed quality and preserve the seed's transmissibility. Hence, there is not too much difference of yield between purchased seeds and self-preserved seeds. The other possibility is that the quality of wheat seeds purchased in the local market with high price has no remarkable difference with the quality of wheat seeds preserved by farmers themselves.

CHAPTER 6

IMPACT OF IRRIGATION WATER PRICING REFORMS ON WATER USE AND GRAIN PRODUCTION

This chapter further estimates water use elasticity with respect to irrigation water price and irrigators' behavior of cropping pattern choice. Combined with the results in the previous chapter, the potential impact of irrigation water pricing reforms on water use, grain production and irrigators' welfare can be quantified.

6.1 Introduction

Values for water demand elasticity of prices vary greatly based upon many factors including irrigation season, and region. The available studies show that the elasticity of water demand with respect to water prices is low particularly in the agricultural sector (de Fraiture and Perry 2002).

In the short-term, irrigation water demand elasticity reflects the changes in water withdrawal and total water consumption, in response to changes in water prices, including the substitution of various inputs such as labor and fertilizer. The longer term response of beneficial irrigation water demand to water prices is determined also by the response of water use efficiency to water prices. Higher water prices are expected to induce improvements in irrigation technology and reductions of water use, but there lacks enough evidence to prove the hypothesis. Rosegrant et al. (2002) assumes basin water use efficiency with respect to water prices for the analysis of the impact of water price changes on water use and food production in the long term. Moore et al. (1994) applied a model of the multi-outputs firm and cross-sectional micro data, from the Farm and Ranch Irrigation Survey, and limited-dependent variable methods to estimate crop-choice, supply, land allocation, and water demand functions for field crops. Farmer-level water demand is decomposed into the sum of crop-level water demands, and crop-level demands are further separated into an extensive margin (land allocations) and intensive margin (short-run water use). Their results show that farmers' responses to water price (measured as groundwater pumping cost) occur primarily at the extensive margin. Schuck & Green (2003) shows that changes in irrigation technology represent one of the strongest potential responses of irrigators to changes in water prices, but this response does have limits. Farm-specific attributes, such as soil type and existing crop selection, can outweigh the effects of water price in irrigation technology selection. All the existing prominent studies have given us a pessimistic scenario of the role of water prices in the farmer's adoption of water-saving technologies.

The estimation of irrigation demand elasticity of water price in China is hindered by the lack of both time-series and cross-sectional data. One direct reason is that irrigation charges did not vary significantly until recently. Meanwhile, the application of cross-sectional data also encounters difficulties, in that, the irrigation water demand elasticity of water prices is influenced by an array of factors, relating to site-specific conditions. Generalizing site-specific characteristics in the cross-sectional modeling may derive invalid results. Another problem encountered in estimation of price elasticity of water demand, for irrigation in China, is that the water fee is charged at a flat rate on the basis of arable land in most of the areas.

However, we can still try to estimate the impact, of water prices, on water use, grain production and irrigators' welfare using the similar methods of Moore's (Moore et al. 1994).

6.2 Theoretical model and data

Farmers engaged in irrigated agriculture make a variety of decisions concerning crop choice, land use, and irrigation water application. A farmer chooses which crops to grow from a set of m irrigated field crops common to a region. Each farmer typically grows two or more crops. Thus, the crop-choice decision can be regarded independently as a discrete choice. However, taking into account the specific characteristics of the surveyed irrigation districts, we can assume that producers make a certain decision of crop-choice rather than in a probability. So, the first step decision which simply involves a discrete choice on whether to grow a particular crop is negligible in this study. The farmer decides the quantity of cropland to allocate to each crop. As an irrigator, the farmer also makes crop-level water decisions; these are conditional on land allocations, reflecting water use within an irrigation season.

Water is modeled as a variable input in the short run. With the normalized quadratic profit function as the form of the crop-specific restricted profit functions, the estimable forms for water demand functions are linear in the exogenous variables.

$$w_i = \mu^i + v^i p_i + \sum_{v=1}^{z} \omega_v^i r_v + \varphi^i b + \upsilon^i n_i + \sum_{s=1}^{t} t_s^i x_s \qquad i=1,\ldots..m \qquad (1)$$

Where:

W_i is the irrigation water applied to crop I; U_i, is the intercept of water demand function. V^i ω_v^i ψ^i V^i t^i are the parameters needed to estimate; p_i is the output price of crop i that farmers take as given; r_v is a vector of variable input prices except water price; b is the irrigation water price; n_i is the land allocations to crop i; x_s is a vector of other variables exogenous to the farm or crop (climate, weather, soil quality, and irrigation technology referred as fixed input in the short run).

Both Jinghuiqu and Shijin irrigation districts are conjunctive in water use. We blend surface and groundwater resources per Mu as the dependent variable, taking the ratio of surface water resources as an explanatory variable.

Optimal land allocation functions, n_i^* are assumed to be linear in the exogenous variables. The estimable forms are:

$$n_i^* = \alpha^i + \sum_{j=1}^{m} \beta_j^i p_j + \sum_{m=1}^{z} r_v^i r_v + \sigma^i b + \psi^i N + \sum_{s=1}^{t} \eta_s^i x_s \qquad i=1,\ldots..m \qquad (2)$$

Where:

α^i is the intercept, β_j^i is the parameter of the prices of multiple outputs, r_v^i is the parameter vector of other inputs except water, σ^i is the parameter of water price, ψ^i is the parameter of total arable land constraintsÿ η_s^i is the parameter vector of other exogenous variables.

With crop-level data, farm-level water demand can be decomposed into the sum of crop-specific water demands. Moreover, crop-level water use can be decomposed into analysis of the extensive margin of water use and the intensive margin of water use.

The impact on the farmer's welfare can be depicted further. Only on the condition that, if the farm-level water demand elasticity of price is greater than 1 (elastic demand) then the farmer's welfare will increase if water prices increase. However, if water price is inelastic (less than 1) then increasing water prices leads to a reduction of the farmer's welfare. A brief derivation is as follows:

Let I_0, I_1 is farmer's expenditure on water use, Q_O and Q_1 is water use, where water price is $P^0$and P^1, respectively. The difference is:

$$\begin{aligned} \Delta I &= P^0Q_O - P^1 Q_1 = p^oQ_0 - p^1Q_0 + p^1Q_0 - p^1Q_1 = \Delta p * Q_o - p^1 * \Delta q \\ &= \Delta p * Q_o(1-(\Delta Q/Q_0)/(\Delta p/P^1) \\ &= \Delta p * q_o(1-E_P) \end{aligned} \tag{3}$$

Where: E_P is farm-level water elasticity.

If E_P is greater than 1 and ”p is negative, then ”I is positive (this implies that the farmer's expenditure decreasing is the same as the farmer's welfare increasing) with increasing water prices. Inversely, if E_P is less than 1 and ”p is negative then ”I is negative (this implies that the farmer's expenditure increasing is the same as the farmer's welfare decreasing) with increasing water prices.

We can hypothesize that the price elasticity of farm-level water demand is inelastic, otherwise, water supply authorities cannot have intensive inclinations to increase water price to fully recover water supply cost.

Figure 5a. Farm-level water demand. 5b. The relationship between crop yield and irrigation

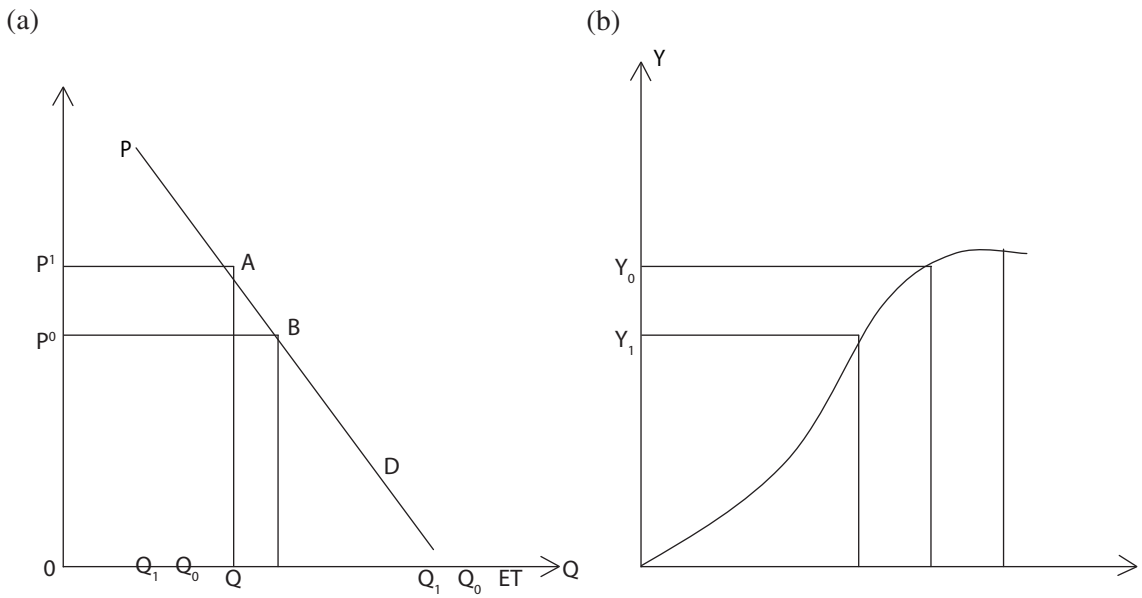


Figure 5a illustrates the water demand curves. Revenue is given by the area P^0BQ_oO which is the same as the farmer's expenditure with water price P^0. When water price increases from P^0 to P^1, the farmer's expenditure is the given area of AP^1OQ_1. Meanwhile, reduction of water use may induce the reduction of crop yield, if irrigation is at the insufficient stage. Figure 5b illustrates the relationship between crop yield and irrigation. If the irrigation water that can be used for crop is less than ET of the crop, the crop yield will be affected indirectly by water price. This will indirectly induce the reduction of farmer's income.

6.3 Estimation and results analysis

6.3.1 Water demand with respect to water prices at crop level

Constrained by the available data, we just estimate the water demand elasticity of water prices for wheat and maize at crop level. The data excludes the sample in Wudu, where water is charged at a flat rate. In Jinghuiqu and Shijin, the data of water price per cubic meter is calculated as the ratio of total irrigation expenditure of irrigation water at the field level. The prices of agricultural products were the average prices at the village level in 2002, due to the lack of data of prices of agricultural production at farming gate level in 2002. This may negatively affect the estimation of the parameters of prices. For the sake of reflecting the influence of precipitations in different villages, we choose dummy variables of that farmer's knowledge on precipitations as agent variable. We asked farmers how they think the precipitation in 2003, whether it is much less, less, normal, higher, or much higher than the general precipitation in the past. The discrete variable of the farmer's answer may affect the farmer's irrigation behavior. Another reason we chose this discrete variable as agent variable of real precipitation is because it is hard to collect the precipitation data at the crop level. Soil dummy variable represents cropland quality. Region dummy variable represents specific characteristic differences between the two regions. Table 10 presents the econometric estimated results.

The goodness of fit measure, Pseudo R^2, is around 0.171 and 0.347 for the wheat and maize function, respectively, which is acceptably high for analysis that uses cross sectional data. The coefficient is also jointly significant.

The results show that surface water price significantly affects water demand at the crop level. The marginal effect of wheat water use with respect to water price is 381 m^3/Yuan. This means that, field water use for wheat decreases 3.81 m^3/Mu if the current water price, increases 0.01 Yuan/Mu. Because we use the linear function of water demand, water price elasticity is not constant. The current field water use for wheat in Jinghuiqu and Shijin is about 272 m^3/Mu and 258 m^3/Mu, respectively, if the farmer cannot increase the groundwater ratio and the delivery efficiency is kept constant at 0.45 (in fact, the groundwater ratio is an endogenous variable which is affected by the groundwater marginal cost and surface water price and other variables. We should use two-step estimation methods to solve these problems. Due to the limitations of available data, we simplify the problems here.), water diversion for irrigating 1 Mu at the head of the main canal will decrease 8.5 m^3, given water price increases to 2.72 Yuan/Mu in Jinghuiqu or 2.58 Yuan/Mu in Shijin. Assuming that the total wheat crop area is 66,600 ha in the two irrigation districts, water diversions will reduce or save 10 million m^3 with an increase of 0.01 Yuan of water prices per cubic meter. This implies that the farmer will increase expenditure on water use 2.064 Yuan per Mu for wheat in Jinghuiqu and 1.97 Yuan per Mu in Shijin. Due to water use reduction, wheat yield will decrease. In the Jinghuiqu district, wheat yield per Mu will Further assuming 1 Yuan/kg for wheat in the market, the farmer's revenue decreases 0.176 Yuan in Jinghuiqu and 0.185 Yuan in Shijin. In sum,

Table 10. Crop water demand with respect to water prices.

	Water demand (m^3/Mu OLS)			
	Wheat		Maize	
Independent variables	Coefficients	T-value	Coefficients	T-value
Price of wheat (Yuan/Kg)	5.32	0.03	-	-
Price of maize (Yuan/Kg)	-	-	7.158	0.05
Price of water (Yuan/m^3)	-380.899***	-3.09	72.001	0.9
Ratio of ground water	-15.255	-0.63	113.314***	4.52
Price of fertilizer (Yuan/Kg)	-13.851*	-1.73	-27.217	-0.87
Dummy variable for sand soil (Yes 1, no 0)	-10.67	-0.21	37.334	0.88
Dummy for loam land (Yes 1, no 0)	10.702	0.2	14.116	0.33
Dummy for clay land (Yes 1, no 0)	-6.387	-0.12	-17.901	-0.43
Dummy for less rainfall (Yes 1, no 0)	67.778	1.09	49.338	0.85
Dummy for same rainfall (Yes 1, no 0)	95.06*	54.93	27.833	0.55
Dummy for higher rainfall (Yes 1, no 0)	45.959	0.87	-26.086	-0.54
Dummy for much higher rainfall (Yes 1, no 0)	68.748	1.02	-104.455	-1.6
Dummy for Shijin (Yes 1, no 0)	8.559	0.33	137.351*	5.86
Intercept	318.264	2.5	45.215	0.49
Observations	132		130	
Adjusted-R^2	0.171		0.347	

*** Represents significance at 1%,* represents significance at 10%.

the total welfare of the farmer will decrease 2.24 Yuan in Jinghuiqi and 2.15 Yuan per Mu, if water price increases 0.01 Yuan per cubic meter.

The results show that output prices and fertilizer price do not significantly affect water demand. This is not identical to our expectations. Maybe the price data at the village level do not reveal farmers' responses to the prices.

Water demand for maize is not significantly affected by surface water price because of small amounts of surface water used. The marginal cost of groundwater resources should be used for the estimation of water demand elasticity in the groundwater irrigation area. The results provide some information of the impact, of surface water prices increasing, on water use, maize production and farmer's revenues. If farmers cannot use more groundwater, increasing surface water price will directly increase farmers' water expenditure on maize production. In the Shijin irrigation district, almost total groundwater resources are used for maize production and increasing surface water prices has no significant impact on farmers' revenue. However, in Jinghuiqu, expenditure on water for maize increases around 0.8 Yuan/ Mu, if water price increases 0.01 Yuan/Mu.

6.3.1 Land allocation with respect to water prices at farm level

The observations of the function only contain the data in Shijin. Water is charged at a flat rate base on arable land in the Wudu irrigation district, which cannot be used for estimating the influence of water prices on land allocations of farmers. Most farmers plant only wheat and maize in Jinghuiqu. Wheat is a summer harvest crop, but maize is an autumn harvest crop. There is no substitution relationship between wheat and maize production. The cross prices elasticity of wheat and crop can be assumed to be zero. The most possible case in the Shijin irrigation district is the substitution

between the wheat/maize crop pattern and cotton crop pattern. The change of wheat, maize and cotton prices or other input prices can stimulate farmers to adjust crop pattern.

Table 11. presents the estimated results of the influence of water price on land allocation to the three crops. The estimation method is Ordinary Least Squares (OLS). The adjusted R-square statistics range from 0.47-0.757. It is high enough for analysis of the cross-sectional data. The results show that only the explanatory variable, the total arable land, is positive and statistically significant. The other variables that we expect to be statistically significant are all insignificant, which may be caused by the fact that we use prices data at village levels rather than at individual farming gate levels.

Table 11. Land allocation responsive functions.

	Crop area (Mu OLS)					
	Wheat		Maize		Cotton	
Independent variable	Coefficients	T-value	Coefficients	T-value	Coefficients	T-value
Wheat price (Yuan/kg)	6.402	1.18	-	-	12.162	1.34
Maize price (Yuan/kg)	-	-	9.084	1.29	0.982	0.08
Cotton price (Yuan/kg)	0.400	0.57	0.842	1.02	1.202	0.82
Fertilizer price (Yuan/kg)	-0.185	-1.27	0.103	0.11	4.525	1.43
Water price (Yuan/m^3)	-1.888	-0.71	0.784	0.34	0.069	0.07
Ratio of groundwater	-0.808	-1.49	-0.002		-1.485	-1.77
Total arable land (Mu)	0.650***	12.88	0.595***	9.3	0.441***	4.09
Intercept	-2.364	-0.75	-5.227	-0.00	-9.839	-2.15
Observations	73		72		40	
Adjusted-R^2	0.757		0.613		0.473	

*** Represents significance at 1%

6.4 Summary

The estimated results show that the changes of water price in farmers' acceptable range will not significantly lead farmers to change crop pattern, but may slightly cause farmers to reduce water demand at crop and farm level. The changes of water prices will influence wheat production slightly, as farmers reduce water use due to increasing water prices. However, if water prices increase too much, it will seriously affect wheat production.

- Water price (rigorously, surface water price) slightly affects surface water use, because most farmers use groundwater for irrigating maize and the ratio of surface water use is small. Increasing surface water price may increase the use of groundwater resources.
- Increasing water price for irrigation enlarges social inequalities. Farmers with lower incomes undertake the reform costs, but the water suppliers with higher incomes gain the benefits of the water price reforms. This is a kind of policy that punishes the poor and awards the rich.
- There are several limitations of the analysis. First, variables for crop prices have little cross-sectional variations at the village level; Second, the substitution of surface water and groundwater resources have not been quantified; Third, the estimated parameters may not be suitable for the aggregate models of irrigated cropping, as most of the cash crops have not been included in the model.

CHAPTER 7

FIELD CANAL MANAGEMENT AND WATER FEE COLLECTION

In this chapter, we attempt to utilize the empirical evidence of the management reforms and irrigation water fee collections at field canals, for the analysis of irrigation water pricing reforms in three IDs.

7.1 Introduction

Water accounting and management up to the intakes of field canals are generally easy for governments because of the good conditions of volumetric facilities. However, it is hard to manage water at the field canal level limited by the water conservancy projects since local townships or village managers often collect various fees in the name of water fees. The water price administrative authorities of the central government think that this is one of the key causes needed to improve water pricing reforms. They think water fee collected by the irrigation bureau is not too high, but the actual water fee submitted by the farmer is generally not too low because of the chaos of farm canal management. Illegal collection and the arbitrary increase of water fee in some regions, negatively affected rational water price increases and enlarged the farmer's financial burden. Illegal collection of water fee has seriously impeded water pricing reform (MWR 2003a). The administrative authorities of the central governments are planning to expand the scope of state management of water prices to the farm-site level, previously managed by village leaders. The key idea of these reforms is to implement the end-price method, which refers to local administrative authorities of water prices accounting the water price standard for each individual household. The household is charged according to the accounted standard. The Jinghuiqu irrigation district has been set as an example. The Shanxxi provincial government has been increasing water prices and carries out the end-price method as well. They lay down the standard of farm-site water price including three components: Water fee collected for irrigation bureau, water fee collected for irrigation station and water fee collected for village and WUG.. The administrative authorities of water price monitor water fee collections in the process of water supply. However, water price authorities accounting water supply costs of field canals may tremendously increase the transaction cost of water supply. This is not inconsistent with the reform orientation of the management of the water supply project. It is necessary to analyze the management and water pricing reforms at field canal levels.

7.2 Basic information of the surveyed field canals

Sixty field canals are surveyed in the three IDs (Table 12). The field canal with the biggest command irrigation area, in one village, is chosen as a sample. In general, the command irrigation area of the observant canals ranges from 70-4,800 Mu. The length of the fixed channel ranges from 220-16,990 m. The average flow rate is between 0.014—2.500 m^3/s.The physical conditions of field canals are greatly different over the three irrigation districts. The average lining rate of channels surveyed is around 40.4 percent. The highest is in Jinghuiqu, about 76.5 percent, and the lining rate of 75 percent of total observant canals range from 80-100 percent. The standard of field canals in Wudu is the lowest. The lining rate of observant canals is around 40.5 percent. Field canals in the Shijin irrigation district generally have both irrigation and drainage functions. Lots of mini-type pumping machines

needed for irrigation at the field level. Only small parts of gravity channels are already lined. The lining rate of observant channels is just around 16.7 percent.

Trapezoid, rectangle and U are the three main types of lining canals, wherein the U type, around 76 percent of observant canals, accounts for the main part. The U type of observant canals in the Wudu irrigation district accounts for 60 percent. Thirty-six surveyed canals are gravity canals and 24 canals need lifting. Most of the irrigation pumps are diesel engine or diving. Some areas need various levels of lifting stations. The average command area of the canals is only about 0.18 Mu/m. Since the conveyance systems of field canals are imperfect in Wudu, water supply cost is very high. 65 percent of the irrigation area needs a lifting station. Most of the canals are gravity in Jinghuiqu. But small portions of canals have irrigation and drainage functions in Shijin, Where canals which need lifting for irrigation account for 45 percent.

Table 12. Physical conditions of field canals in the three irrigation districts.

	Observations	No. of non-lining	Total length of channels (m)	Total length of cement concrete linings (m)	Lining rate (%)	Average irrigated area per m of channels (Mu/m)
WDID	20	7	69,300	28,030	40.4	0.18
JHQID	20	1	32,365	24,765	76.5	0.42
SJID	20	17	53,280	8,870	16.7	0.44

Source: Authors' survey.

7.3 Crop irrigation requirements and irrigation efficiencies

7.3.1 Irrigation institution and sources

The irrigation season in the three IDs is totally different. Thirty-nine irrigation days in one year in Jinghuiqu concentrated in winter, spring and autumn for wheat or summer for maize. Irrigation days vary greatly in Wudu. The lowest is just one week, but the highest is about 60 days. Most irrigation is for the initial stage of paddy. Irrigation days in Shijin are the shortest, only around 15 days. Irrigation days for wheat concentrated in the spring or winter irrigation season. Irrigation for grain and other cash crops are mostly conjunctive water use in Jinghuiqu, where 79.1 percent of wheat, 55 percent of fruits, and 49.9 percent of maize in the command area of surveyed canals use surface water resources. However, almost all vegetable uses groundwater resources for irrigation. In Shijin ID, 64 percent of wheat, 60.2 percent of fruits, 50.4 percent of cotton, and 16.1 percent of vegetable use surface water resources and almost all maize uses groundwater resources. Table 13 lists out the water sources for main crops.

7.3.2 Crop irrigation quotas at field level

Table 13 presents irrigation quotas for main crops at field level. Irrigation is supplemental for paddy. Field irrigation quotas are 247 m^3/Mu on average, but in the drought period, farmers often carry water for irrigation (informal irrigation). Irrigation quotas for maize, wheat, oilseeds and field vegetable is usually around 3-5 m^3/Mu. Net irrigation for wheat and fruits in Jinghuiqu and Shijin is almost the same. In Jinghuiqu and Shijin, irrigation quotas for wheat are around 230.2 and 214.4 m^3/Mu, and for fruits it is around 183.3 m^3 and 220 m^3/Mu, respectively. However, irrigation quotas

Table 13. Irrigation water sources for main crops (%).

	WDID		JHQID		SJID	
	Surface water	Groundwater	Surface water	Groundwater	Surface water	Groundwater
Wheat	100	0	79.1	20.9	64.0	36.0
Maize	100	0	49.9	50.1	0.0	100
Cotton	-	-	-	-	50.4	49.6
vegetable	100	0	0	100	16.1	83.9
Fruits	-	-	55.0	45.0	60.2	39.8

Source: Authors' survey

for maize and vegetable are greatly different in the two IDs. It is around 205.7 and 115.7 m^3/Mu for maize, and 786 and 295 m^3/Mu for vegetable, respectively.

Mixed irrigation quotas at the farmland level. There are various types of irrigation in the conjunctive water use area. Low-pressure pipes are used to deliver water directly into the field or irrigation needs one pump well or several pump wells (in general, two or three pump wells) to pump water into the field canal. In some area where surface water volume is not enough during the irrigation season, farmers often pump groundwater into the canals blended with surface water for irrigation. In only portions of field canals groundwater resources are used for irrigation, field irrigation quota varies greatly over regions and among different irrigation methods, so that only field irrigation quotas of surface water are calculated. In Wudu, in the case of the current crop pattern, field delivery efficiency ranges from 0.53-0.95, and field irrigation quota is around 300 m^3/Mu. In Jinghuiqu, field delivery efficiency is between 0.74-0.95, and field irrigation quota is around 303 m^3/Mu. In Shijin, field delivery efficiency is between 0.63-0.96, and the field irrigation quota is around 182 m^3/Mu.

7.3.3 Analysis of irrigation quotas for crops

Crop irrigation quotas vary greatly in the three IDs. According to ET of crops provided by the local irrigation stations and ET of crops in the map of *crop ET isoline around China,* completed in 1993, the observant crop irrigation quotas at the field level features in 5 aspects:

- Field irrigation quotas in parts of gravity or lifting irrigation areas in Wudu, are two or two and a half times more than crop irrigation requirements, due to low expansions of field water-saving technologies, large size of irrigation land parcels, uneven arable land, or flood irrigation.
- Field irrigation quotas in the upstream regions, in the vicinity of water sources, are higher than crop irrigation requirements although in these regions, water-saving technologies are adopted to some degree.
- Field irrigation quotas are approximate to crop water requirements in the regions where water resources are comparatively plentiful and field water-saving technologies, such as the border method of irrigation, are adopted extensively. This is prevalent in Jinghuiqu and Shijin.
- Field irrigation quotas are lower than crop water requirement in the downstream regions or highland, where irrigation is difficult or the pumping cost is high.

Table 14. Net irrigation quotas for main agriculture crops at field level.

	WDID			JHQID			SJID		
	Yield (Kg/Mu)	Irrigation times	Irrigation quota (m^3/Mu)	Yield (Kg/Mu)	Irrigation times	Irrigation quota (m^3/Mu)	Yield (Kg/Mu)	Irrigation times	Irrigation quota (m^3/Mu)
Wheat	292.4	1-2	2.9	423.9	1-4	230.2	432.2	1-4	214.4
Maize	357.6	1-4	3.5	456.8	1-4	205.7	470.0	1-2	115.7
Cotton							216.1	1-2	125.7
Rice	522.6	1-4	247						
Vegetable		3-5	4.7		10-15	786.0		4-8	295.0
Fruit					2	183.3		1-4	220.0

Source: Authors' survey

- Field irrigation quotas are much lower than crop water requirement (around 70-80 percent) in some regions, where water resources are seriously scarce. Crop yield is very low.

Since the cost of adoption of water-saving is high in Wudu, where water resources are comparatively abundant, the extensive adoption of water-saving is not economic. Meanwhile, in the upstream regions in the Jinghuiqu and Shijin IDs, the water loss often recharges groundwater resources often to be reused. In these regions, it seems that the potential of water saving is low in terms of the volume of current water use.

7.4 Management methods for field canals

Four management modes of field canals already exist since the irrigation management reforms in the past two decades. They are contracted responsibility, rent, WUAs and village collectives. The management modes of observant field canals in Wudu are mainly village collectives and WUAs, but village collective management accounts for the majority. In Jinghuiqu, contract management mode of field canals, which the lateral canal heads and other water managers are responsible for, accounts for the majority. In Shijin, WUAs are established among several villages for managing field canals (villages with large irrigation area usually establish WUAs separately). Field canals are still managed by village committees. Some villages adopt contract systems.

Although the management of all surveyed IDs is different, the limited scope and degree of the farmer's participation in the management of field canals are similar. Of the 60 observant canals, the management mode of 39 canals is determined by the village leaders and that of 19 canals is determined by the local governments or irrigation bureaus. None of canals' management mode is determined by farmers. Table 15 presents the situation of the decision rights of the management modes.

Table 15. Decision rights of management modes of the observed field canals.

	By governments or irrigation districts	By villages	By farmers	By others
WDID	7	12	0	1
JHQID	10	9	0	1
SJID	2	18	0	0
Total	19	39	0	2

Source: Authors' survey.

7.5 Water fee collection, operation and investment

7.5.1 Water fee collection

7.5.1.1 Water fee collection methods

Table 16 presents water fee collection methods of observant canals. Water fee of 39 field canals is collected at a flat rate basis on area, of 19 field canals water fee is charged on the basis of water volume and water fee of 2 field canals is proportionally charged to the population.

Table 16. Numbers of field canals using different charge methods.

	Flat rate	Volumetric rate	By population
WDID	18	0	2
JHQID	3	17	0
SJID	18	2	0
Sum	39	19	2

Source: Authors' survey.

Thirty-four managers who are responsible for the collection of water fees directly settle accounts with the irrigation stations, 25 managers settle accounts with the village committee and one manager settles accounts with the township government. Most of them settle accounts after irrigation in Shijin and Jinghuiqu. Managers in Wudu collect water fees at a regular time, as they collect water fees at a flat rate, which largely depends on administrative power. Of 60 managers of field canals, 25 managers are village leaders, 12 managers are agents of WUGs and 14 managers are contractors. In Wudu and Shijin, most of the managers who are responsible for water fee collection are village leaders.

The incentives to managers for water fee collections are very interesting and are worthy of noting - 88 percent of total managers have additional payments for water fee collection, besides their salary as a village leader. The amounts rewarded to managers are determined according to the collection ratio or amounts of water fee collected. Some managers do not have marginal benefits for water fee collection, because they are paid a salary and water fee collection is included in the scope of their duties.

7.5.1.2 The status of water fee collection

Water fee in two field canals is proportionally collected to population in Wudu. One is 18 and the other is 26 Yuan per capita. 18 field canals are charged at flat rates. Water fee is around 37 Yuan/Mu. The local prefecture government regulates that the highest water fee should not exceed 43 Yuan/Mu. However, in 3 observant field canals water fee reaches to 70, 72 and 110 Yuan/Mu. In Jinghuiqu, there are 3 field canals where water fee is collected on the basis of Mu. The average water fee is about 37 Yuan/Mu. Water fee in 17 field canals is collected by volume. Water fee per cubic meter is 0.162 Yuan. At the intake of field canal, water volume for each farmer is measured by the flow time, and this requires volumetric facilities with high quality and low costs. Several farmers complain that water flow is not steady and they are unwilling to submit water fees. In Shijin, water fee in 17 field canals is charged on the basis of Mu and irrigation time. The charge for one irrigation time is

around 40 Yuan/Mu. The maximum reached 97 Yuan/Mu. Collection ratios of water fee in Jinghuiqu and Shijin reached to 97.3 and 98.6 percent, respectively. However, only in 4 field canals, water fee collection ratios in Wudu reach 100 percent. Farmers are unwilling to pay water fees to some degree. Currently, it is more difficult to collect water fees in these regions where water fee is charged at a flat rate.

7.5.2 Investment and operation cost for field canals

Water supply costs up to the lateral intakes are systematically accounted, however, water supply costs of field canals have not been accounted in general. Water supply costs include fixed costs and operational costs. Table 17 presents the surveyed results. The average cost of water supply of the field canals are around 0.04 Yuan per cubic meter. The investment per Mu is around 114 Yuan in Wudu, 115 Yuan in Jinghuiqu and 57.7 Yuan in Shijin.

Table 17. Water supply cost under the intakes of the surveyed field canals in 2003.

	Total cost (Yuan)	Water discharge (m^3)*	Water cost (Yuan/m^3)
WDID	131,099	2,211,844	0.059
JHQID	112,457	2,651,160	0.042
SJID	136,308	3,699,556	0.037
Total	379,864	8,562,560	0.044

Source: Authors' survey.
Note: water volume discharged is measured at the intakes of field canals, including water loss in the field.

7.6 Summary

Water resource endowments and water conservancy projects determinate the water tariff designing, water prices collection methods and the relationships among irrigation management organizations, village committee and water users.

The Wudu irrigation bureau manages main canals, township governments and village committees manage field canals. Water fees are collected on a flat rate basis on arable land. Collecting water fees depends on village administrative organizations to a great extent. The scope and degree of farmers' participation in irrigation management is fairly low. The collection ratio of water fee is not high. The farmers' attitudes towards water price reforms are very intensive. In Jinghuiqu, contract management is predominant. The volumetric water fee method has almost been implemented for each household. The collection ratio of water fee is very high. Water is extensively taken as an economic good. The chain of irrigation management is that the irrigation bureau contracts with irrigation stations and irrigation stations employ sectional heads who hire lateral canal heads. The managers are given incentives by payments according to water use. The management mode clearly defines the rights and duties of each management position. In Shijin, water volume is measured at the intakes of field canals constrained by the irrigation facilities. It is hard to collect water fees on the basis of water volume for each household. In such situations, WUAs are established on the basis of irrigation stations, but water fee collection at the village level depends on administrative power of the village to a great extent. The irrigation bureau still needs the assistance of the village leaders, in water fees collection and irrigation management.

It is worthy of paying more attention to the water users burden on water loss in the fields. Because more water use for farmers, and more revenue for irrigation bureau, it is impossible that the irrigation bureau has strong incentives to adopt water-saving technology at the field canal level.

Other issues should be emphasized. The end-price method is good for water pricing management in these regions with good irrigation infrastructure, especially with good water measurement facilities. However, in these regions, due to the lack of volume facilities, the end-price method needs tremendous investment on irrigation infrastructure, which may increase water supply cost greatly. It is not economic to implement this method in these regions.

CHAPTER 8

GROUNDWATER RESOURCES MANAGEMENT

The exploitation and utilization of groundwater resources is closely linked with surface water use. Price change of surface water affects the utilization of groundwater, especially in the IDs of conjunctive water use. In this chapter, with the data of irrigation well management and groundwater utilization in Jinghuiqu and Shijin, we explore the ongoing groundwater management and reforms in China.

8.1 Introduction

China is endowed about 828.8 BCM of groundwater resources, of which the maximum utilizable amount is around 122.5 BCM (Liu and Chen 2001). Rational exploitation of groundwater resources plays an important role in the economy. Conjunctive use of water resources is beneficial to protect soil from salinization in some areas. However, due to the rapid growth of water diversions, the overexploitation of groundwater is prevalent in the plain area, leading to very serious ecological and environmental problems in China.

After 1980, the growth rate of surface water supply was negative, while the proportion of groundwater supply is becoming higher and higher in the Huang-Huai-Hai and inland river basins. In the Haihe River Basin, the proportion of groundwater diversions over the total has reached 68 percent in 2000. In Hebei province, it was about 75 percent in 2003. In the Shaanxi province, groundwater resource diversions were 3.4 BCM in 2003, accounting for 45 percent of the total (MWR 2003b). In the east of the North China Plain, groundwater resources are mainly from deep aquifers, which contain high fluorine and it is hard to be recharged, due to unavailable freshwater in shallow aquifers. Maintaining the current exploitation intensity, the existing stocks of deep groundwater resources will be exhausted in nine or ten years. Once these groundwater resources are fully exploited, it will take at least 150-200 years to recharge it even without utilization. Major parts of the Hebei province are located in the North China Plain, where groundwater resources are seriously overexploited nowadays. In the GuanZhong Plain area of the Shaanxi province, the groundwater overexploitation is very extensive because of rapid development of the economy and water resource scarcities.

In China, states own the property of water resources. To guarantee the rational development and utilization of groundwater resources, the utilization permit institution of water resources has been implemented. The State Council issued the rule of the implementation of the utilization permit of water resources in 1993. The regulation prescribes that any organization who plans to develop water directly from a river, lake or groundwater, by means of engineering or mechanical means, must apply for a permit. The third and fourth section prescribe that permits are not necessary on the conditions of, small amounts of water being used for irrigation or for fighting emerging drought. The 36th section in the 4th article of the Water Law prescribes that local governments up to county level should take strict measures to control groundwater exploitation, in those areas where groundwater resources are overexploited. The prohibition zones of groundwater resources can be set after the authorization of provincial governments in the areas of serious overexploitation of groundwater resources. As for the development of groundwater resources in the coastal area, scientific approvals and effective measures must be adopted to be against land subsiding and the intrusion of seawater.

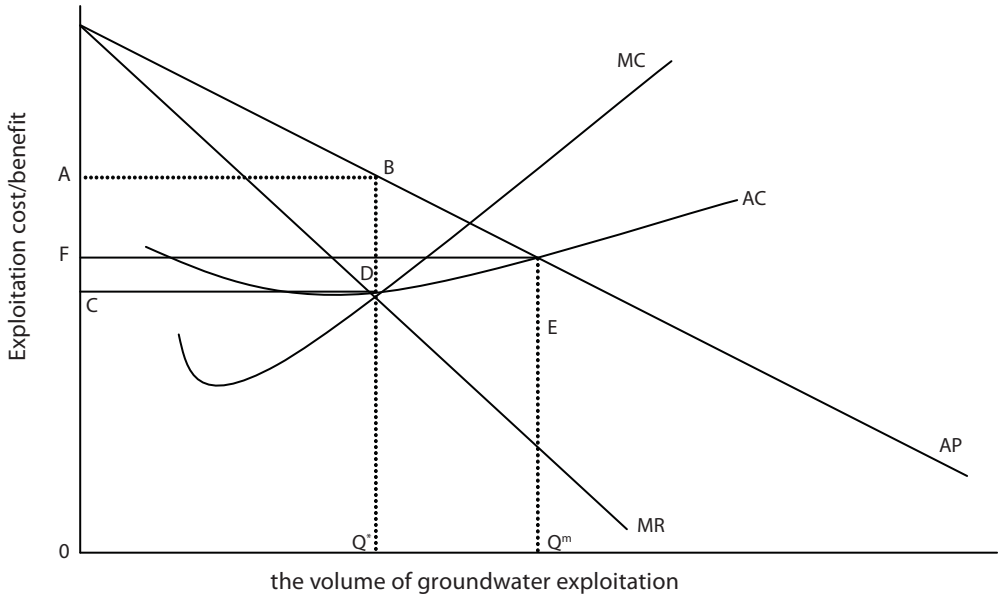
The MWR and other authorities have enhanced protection and management of groundwater resources and launched the Protecting Groundwater Campaign in 2003. Hebei provincial government has already mapped out these overexploiting zones and serious overexploiting zones according to the overexploitation degree of groundwater resources. In 2003, the Shaanxi provincial government launched the *Protecting groundwater Campaign,* which took measures to protect groundwater from overexploitation in three stages as follows: In the first stage, a dynamic monitoring system of groundwater exploitation, management and supervision mechanism in the zones of groundwater overexploitation is established. By the end of 2005, the overexploitation volume in urban areas and the groundwater irrigation area in the Guanzhong area should be dropped by more than 30 percent to effectively control the groundwater water table from dropping further, year by year, in overexploitation zones. In the second stage, a dynamic monitoring system of groundwater exploitation and water resources management institution are further improved in groundwater overexploitation zones and the total volume of groundwater exploitation are strictly controlled. By 2010, the overexploitation amounts should be dropped by 50 percent, on the basis of the reduction of overexploitation in 2000. The trend of overexploitation should be reversed. Ecologic and environmental problems caused by groundwater overexploitation should be controlled effectively. In the third stage, groundwater overexploitation is fully controlled and the ecological environment is improved considerably. By 2020, water resources should be kept balanced between utilization and recharge in all areas, groundwater overexploitation should be completely eliminated and the goals of controlling overexploitation and effectively managing groundwater are totally achieved.

On the one hand, the country has issued lots of regulations to protect groundwater from overusage. On the other hand, the problem of groundwater overexploitation is getting more and more serious rather than being effectively solved. The management methods adopted by the government seem to have failed in practice. The status of groundwater resources development and management is worthy of further analysis. The surveyed data on groundwater resources, in the Hebei and Shaanxi provinces, is used for testing the model of exploiting groundwater resources of openness to access.

8.2 Groundwater resources development: A theoretical model

According to economic theory, as for resource exploitation and utilization in a market economy of perfect competition, if marginal cost equals marginal benefit, producers maximize profits and resources are efficiently utilized. From the perspective of property rights, it is necessary to define property clearly, say extensive, excludable, transferable and enforceable. However, the producer doesn't exploit and utilize resources usually complying with the marginal law that always results in market failure, because some goods have public attributes, production has externalities and transaction information is asymmetric. In these cases, policy instruments should be used to guarantee the rational exploitation and utilization of natural resources. In China, the state has the ownership of groundwater and the practical usufruct is allocated to water users at all levels. The local administrative departments are responsible for the management. Groundwater property is not defined and enforceable. Without effective measures, on the principle that first come to first use, groundwater resources are deemed to be overexploited. Figure 6 presents the theoretical model.

Figure 6. Theoretical model for the groundwater exploitation without defining water rights



The vertical axis refers to the cost/benefit of per unit of groundwater exploitation. The horizontal axis refers to the volume of groundwater exploitation. AP is the average revenue curve or demand curve, which slopes from the above right to the below left, because of the marginal profit diminishing law. The MR curve under AP is the marginal revenue curve. MC is the marginal cost curve and AC is the average cost curve. MC intersects with AC at point D, the lowest point of the AC curve. In the groundwater exploitation model, of which the groundwater property is defined clearly, the owner of groundwater will exploit groundwater resources represented at point D, the intersection of MC and MR. Under this condition, as shown in Figure 6, groundwater price is OA and the optimum exploitation volume of groundwater resources is Q*0The gross cost of exploitation of groundwater is the area of rectangle OCDQ* and the return of resource owner is maximal. This way of resource utilization can guarantee the resource owner to get scarce rent of the resource, which is represented by the area of rectangle ABCD. However, if the property right of the resource is not clear, the exploiter of groundwater will not exploit groundwater on the principle of MR=MC, but on the principle of AC=AP, represented by point E. The exploitation volume of groundwater in the model of groundwater resources, which is open to access, is more than the volume exploited, represented by Q^mQ^*, under the condition that the property right of groundwater is defined clearly. Without clear definition of water property, anyone who wants to protect groundwater resources couldn't get scarce rent of groundwater resources. Therefore, there is no incentive to encourage users to protect groundwater resources and water resources are not allocated to the optimum. Groundwater users will not stop exploiting groundwater, except in the following cases. One is that the groundwater is exhausted. The other is that MC is higher than MR or MR of other resources is higher than MR of the groundwater resources of the existing utilization. In the conjunctive irrigation area, the utilization of surface water and groundwater will be affected markedly by the changing of surface water price. As long as the unit benefit of groundwater utilization is higher than that of surface water utilization, farmers will not utilize surface water as a substitution. Compared with surface water irrigation, groundwater irrigation is more convenient, and timely. Especially, for irrigating cash crops, which needs to be irrigated many times, such as vegetables and fruits, the farmer prefers to use groundwater for irrigation.

8.3 The ongoing groundwater management

8.3.1 Basic characteristics of surveyed irrigation wells

Twenty irrigation wells in the Jinghuiqu ID and 36 irrigation wells in the Shijin ID were random chosen for observation, including 16 irrigation wells in 8 villages in the groundwater irrigated area in the Hebei province. Before 1980, these villages were located in the effective irrigation area of Shijin. Because of surface water resources decreasing, nowadays these areas have become groundwater irrigated areas. The survey includes well depth, well investment, the change of groundwater tables, the structure and the method of collecting water fees, the management system, crop irrigation institution, the management of groundwater exploitation and so on. We interviewed one well manager in each village. Wells with moderate scale of irrigation area in one village is observed. If the well manager manages more than one well, the one with the largest irrigation area were chosen. Table 18 highlights the basic information of the surveyed irrigation wells.

Table 18. Basic characteristics of observed wells.

	Well depth (m)		Command irrigation area (Mu)		The maximum pumping water	The practical pumping water
	Mean	Max.	Mean	Max.	m^3/hr.	m^3/hr.
JHQID	68	132	143	480	38	33
SJID	158	354	112	300	45	38

Source: Authors' survey

The well in Shijin is much deeper than that in Jinghuiqu. The depth of the deepest well in Shijin reached 354 meters, more than 200 meters than the counterpart in Jinghuiqu. The average command irrigation area of wells in both IDs ranges from 110-150 Mu.

There are many kinds of well property. Of 56 observant wells, 29 wells belonged to collectives, 15 wells were dug by the private organizations, and 12 wells were jointly dug by several farmers. Accordingly, the management of wells varied with the well property. 16 percent of the total adopted stock management, 11 percent adopted contracted management, 4 percent are managed by hired persons, 50 percent wells are managed by private organizations and the rest are managed by owners in turn.

8.3.2 The status of groundwater management

Surface and groundwater resources in the IDs of conjunctive water use are separately managed by different administrative departments. Irrigation bureaus often manage surface water resources and maintain water supply facilities. The county administrative authorities of water resources take charge of groundwater management, including planning, managing and exploiting within the administrative domain. The county governments in the scope of the irrigation district have decisive administrative power in the exploitation and utilization of groundwater. When they decide whether groundwater resources can be used or not, they just take into account the requirements of agricultural development rather than the protection of groundwater resources. For instance, local governments often subsidize farmers to dig wells for fighting drought in serious drought seasons. Once farmers have wells, they prefer groundwater for irrigating cash crops to surface water, even if surface water can meet water

requirements. In many areas, the rights of groundwater resources are not clear and farmers can exploit groundwater without almost any restriction. Several aspects of groundwater management are provided in the following, to specify the ongoing management of groundwater use.

- The status of obtaining permits for digging wells

The local administrative departments of water resources do not attach great importance to the management of digging wells. Whether a well is permitted to be dug or not is often determined by the local village leaders. Of all 56 responders, 80 percent think that digging wells only needs the village leader's authorization. In Jinghuiqu, all responders think that they do not need the authorization of the county government. Only 4 managers of irrigation wells in Jinghuiqu and 9 managers in Shijin applied for permits for digging wells, and 77 percent of responders did not apply for permits.

It is possible that all responders obtained permits in the recent years, in which case observant wells are categorized into two groups: one is before 2000 and the other is after 2000. Of 20 observant wells in Shijin, 12 wells were dug after 2000, but only one with a permit. Of 12 observant wells dug after 2000 in Jinghuiqu, only 2 well managers have permits. Of 13 well managers with permits, 8 managers were authorized by the county administrative departments, 2 by township governments, 2 by the diggers, and 1 by the local agriculture development office.

Of the responders to the question, that why a permit for digging a well is necessary, 76.8 percent do not know, 23.2 percent think it's the government's order and they want to avoid administrative intervention of water use. As for the goal of applying for a permit, 71.4 percent of responders do not know the reason and 28.6 percent answer that digging a well in disorder can be restricted, or the volume of water use can be limited or water resources can be used thriftily.

Of the responders to the question, that whether they can dig a well or not without a permit, 86 percent think it is allowable. Digging a well without order is very prevalent in both IDs.

Of 13 responders with permits, 4 responders think it is difficult to attain. The cost of obtaining a permit ranges from several Yuan to 450 Yuan. These results remind policymakers of the possibility that local governments would be inclined to issue more permits to exploit groundwater resources for obtaining marginal benefits without effective supervision.

In addition, Of 43 responders without permits, 12 think it is unnecessary, 27 do not know and 4 are unwilling to pay for it.

- Fund sources for digging irrigation wells

Both in Jinghuiqu and Shijin, most of the wells were dug during the period between the 1980s -1990s. The cost per meter for digging an irrigation well was between 50-140 Yuan. Funds come from different sources. Some were invested by private organizations, some by village collectives, some by production groups and some jointly by several farming households. But, after 2000, almost all wells were collectively established by shareholders. To be a shareholder, every household should contribute to corresponding funds in accordance with his irrigated area. Some provide funds proportionate to population. Most of the farmers invest irrigation wells for irrigating their own land contracted from the collective.

- Fee collection

There are several methods of collecting water fees. First, farmers directly pay electricity as water fees to the electric management department. The standard of water fees is the same as the standard of electricity. Irrigation well managers cannot obtain any revenue. Second, farmers pay water fees to well managers. Water price equals to the electric rate plus the management rate. For

instance, the Huadaikou village committee in Shijin pays 0.581 Yuan/KWH to the electric managerial department. However, the village collects electric fees from villagers by the standard of 1.0 Yuan/KWH. The price difference is kept as management revenue for managers. Third, well owners pay a fixed salary to the well manager. Maintenance and operational fees of wells are shared by the shareholders. This method is mainly suitable for wells jointly built by several shareholders. Fourth, if irrigation wells are built by collectives, village committees often assign a person to manage wells, village committees give small amounts of money to the managers as salary. In these cases, water fees are collected the same as electric fees. The collectives are responsible for O&M wells. Table 19 presents the collection methods of water fee and the variable cost of groundwater use.

Table 19. Collection methods of water fee and variable cost of groundwater use.

	Electric fee collected by electric department Yuan/KWH	Electric fee collected from water user Yuan/KWH	The method of water fee collection (%)			Cost per cubic meter at well outlet (yuan/m^3)		
			Based on area	Based on power consumption	Based on irrigation duration	Mean	Max	Min
JHQID	0.38	0.75	0	45	55	0.22	0.33	0.14
SJID	0.57	0.63	3	97	0	0.26	0.70	0.11

Source: Authors' survey

The electric price for irrigation in Shijin is greatly different from that in Jinghuiqu. Electric price varies from 0.31 to 0.68 Yuan/KWH. Average electric price is 0.48 Yuan/KWH. As rural electric price for irrigation is different in the two IDs, groundwater supply cost is different. The electric price for irrigation in Jinghuiqu is much lower than that for domestic and that for irrigation in Shijin, where electric price for irrigation is as same as that for domestic. There is not too much difference in water cost at the well outlet for water users in both IDs, even most of the wells in Shijin are very deep and power consumption for pumping per cubic meter of water is, by far, higher than that in Jinghuiqu. The key cause is that digging wells in Jinghuiqu is not only for irrigating crops of the well owners, but also for obtaining profits by selling water to other farmers. There is a great difference between the electric fees paid to the electric department and the electric fees collected from water users in Jinghuiqu. Some observant well managers can obtain 1,000-3,000 Yuan, net profit for one year from selling groundwater. In Jinghuiqu, as the property of groundwater resources are not defined, well managers can exploit public resources without restrictions. The subsidies of electricity essentially give a signal for well managers to overexploit groundwater resources, but water users are not benefited from the government's subsidy for electric power for irrigation.

- Organizations of digging wells

Of 56 observant wells, 44 wells were dug by private organizations, 9 wells were dug by organizations managed by the county governments and 3 wells were dug by organizations managed by the township governments. Private organizations make up the main body of well digging organizations in the rural area because the price for digging wells by private organizations is the cheapest and it is more convenient for farmers to have contact with them. The price for digging

wells by other organizations is much higher and the procedure is very complicated. It is necessary to enhance the management of well digging organizations in the setting of privatization reforms, because the private organizations may canvass the authorities for providing more permits for digging wells to obtain their own economic benefits.

- Responder's knowledge on groundwater resources

To understand the water user's knowledge on groundwater resources, we investigate whether responders know where groundwater resources in wells come from. The surveyed results show that 21.4 percent responders think groundwater resources came from precipitation directly, 8.9 percent think groundwater resources came from canal leakage, 50 percent have no idea, and 19.7 percent think groundwater resources naturally exist. These results reveal that farmers do not know the serious consequences of groundwater overexploitation.

8.4 Consequences of the openness to access

The above surveyed results demonstrate our hypothesis that groundwater resources are open to access without defined water rights. The following further illustrate that groundwater resources are certainly to be overexploited under the current framework of groundwater management.

8.4.1 Groundwater tables are drastically declining in large areas

On average, the static water table declined by 14.2 meters in the 20 observant villages in Jinghuiqu, during the period from 1980 to 2003. In the rapidest declining area, the groundwater table dropped 32 meters, equivalently, by 1.2 meters per year. Of these 20 villages, groundwater tables in 7 villages declined by more than 20 meters. In Shijin, the static groundwater table in 20 villages in the conjunctive irrigation area declined by 14 meters on average. In villages of groundwater irrigated area, the static groundwater table dropped by 29 meters on average. Groundwater resources are being overexploited in most of the observant villages. Table 20 highlights the change of groundwater table from 1980 to 2003.

Table 20. The changes of static water table during the period from 1980 to 2003. Unit: Meter

	1980	1990	1995	2000	2003
JHQID	11	16	20	22	25
Conjunctive irrigated area in SJID	20	23	27	30	34
Groundwater irrigated area in SJID	26	36	43	49	55

Source: Authors' survey

8.4.2 Shallow wells are destroyed and deep wells increase rapidly.

During the past two decades, the total wells in 20 observant villages in Jinghuiqu increased by 405, equivalently, well numbers in each village increased by 20. Shallow wells lower than 50 meters, only increased by 100 and peaked at 673 in 2000. After 2000, shallow wells decreased by 114, in other words, well numbers in each village reduced by 6 in three years due to the rapid decline of groundwater tables. Suppose that the digging cost of one well was 15,000 Yuan, each village lost almost 100,000 Yuan in three years because of well scrap. Meanwhile, a large number of deep wells among 80-120 meters were increased in breakneck pace. After 2000, deep wells in 20 observant villages increased by 168, say, wells in each village increased by 8. Assuming that the cost of digging a deep well was 20,000 Yuan, the total expenses for digging wells in each village in the three years was 160,000 Yuan. Numerous shallow wells dug in 2000 were already destroyed just 3 years later due to the rapid decline of groundwater tables. The scrapping of shallow wells and digging of deep wells result in extreme losses for farmers.

Table 21. The amounts and distribution of wells in 20 villages in JHQID.

year	The amount of wells	The amount of shallow wells	The amount of deep wells	Villages with deep wells
1980	406	422	0	0
1990	534	528	6	1
1995	593	557	36	3
2000	773	637	136	10
2003	827	523	304	18

Source: Authors' survey

Meanwhile, the distribution of deep wells in villages has been changed greatly (column 5 in table 21). Only one village had a deep well (80-120 meters) in 1990, however, in 2000, around half of the villages had deep wells. In 2003, almost all the villages had deep wells except for 2 villages close to the Jinhe River. The conjunctive water use in Jinghuiqu has been changed into overexploiting groundwater resources.

Table 22 presents the situation in Shijin. Wells in 8 observant villages in groundwater irrigated area increased to 529 in 2003, from 418 in 1980. In other words, wells in each village increased by 7 in this period. Wells in 20 villages in surface water irrigated areas have increased by 237, equivalently, wells in each village increased by 11. Shallow wells lower than 50 meters were totally destroyed in the groundwater irrigated area. In contrast, deep wells have increased rapidly. Deep wells more than 200 meters have increased by 23 from 2000 to 2003. Assuming digging cost per deep well was around 80,000-100,000 Yuan, each village has averagely expended 100,000 Yuan for digging deep wells. Deep wells between 50 to 200 meters have increased by 59 only in three years. Similarly, only 5 villages had deep wells more than 200 meters in 1980, however, the numbers had increased to 9 in 2003. Overexploitation of groundwater resources had led to serious land subsiding.

Table 22. The amounts and distribution of wells in observed villages in SJID.

	Wells in groundwater irrigated villages	The total	Wells in conjunctive irrigated villages			The distribution change of deep wells in observant villages		
			Wells lower than 50 meters	Wells between 50 to 200 meters	Wells higher than 200 meters	Wells lower than 50 meters	Wells between 50 to 200 meters	Wells higher than 200 meters
1980	418	294	168	116	10	5	10	5
1990	492	374	133	222	19	5	12	7
1995	506	435	91	316	28	4	15	9
2000	518	467	58	366	43	2	16	9
2003	529	531	45	425	61	1	16	9

Source: Authors' survey

8.4.3 Groundwater irrigation area increase at the expense of the decrease of surface water irrigation area

Total diversions for irrigation at the canal head have dropped, year by year, in Jinghuiqu since 1980. Total diversions for irrigation in 2003 are less, around 0.3 BCM, than diversions in 1980. The surface irrigation area in Shijing has reduced to 1.2 million Mu in 2003, from more than 2 million Mu in 1980. This trend is still continuing. Surface irrigation facilities are seriously damaged in the regions of rapidly increasing groundwater use. Surface water-saving is at the expense of developing more groundwater resources.

8.4.4 Social inequality is expanding

Groundwater resources are state-owned in China. Governments at all levels represent the country to obtain benefits of water resources. However, the country is a very obscure concept. The Water Law prescribes that the State Council represents the country to manage water resources, the usufruct and income right belong to special departments and local authorities in practical. Under the situation of undefined water rights, the rich have more opportunities to utilize groundwater resources than the poor, which impairs the interests of poor farmers and expands social inequality.

CHAPTER 9

CONCLUSIONS AND POLICY IMPLICATIONS

9.1 Conclusions

This study firstly takes stock of the past trends of irrigation water pricing reforms and practical implementations of irrigation water pricing among typical large-scale irrigation districts around China. Further, this report analyzed three Chinese irrigation districts in varying physical and socioeconomic settings so as to gain insights into the future feasibility and impact of full cost recovery irrigation water pricing. At the most basic level, the findings showed that each irrigation district had very different infrastructure - including ability to meter water, overall condition, and sources of alternative supply (i.e. groundwater). Despite these physical differences and differences in canal level management, there was surprising similarity in farmer involvement, or lack thereof, in irrigation decision making which translated into low levels of understanding as to what fees were due and for what purpose, and thus how fees were related to water use and overall irrigation system financing, a problem sometimes exacerbated by the imposition of unofficial fees.

The calculations of basic farm economics and the results from econometric analysis suggested while current irrigation prices may be low relative to supply costs, they are high relative to farmer returns and that additional increases would lead to a decline in production and income, outcomes which go against current government policies to reduce the disparity between rural and urban incomes and to maintain national food self-sufficiency.

The surveyed results of water fee collection, investment and delivery efficiency of 60 observant field canals show that resource endowments determine the management mode and water tariff designing at field canals. In the south of China, despite the management and water fee collection at field canals largely depend on local administrative powers, it is still reasonable. Meanwhile, flat water charging methods, which leads to some degrees of water waste, but it is still a second-best way to pricing irrigation water in the south irrigation area in terms of high cost of transaction costs.

The investigations of pumping wells for irrigation show that groundwater resources are open to access at present. This is the fundamental driving forces of overexploitation of groundwater resources. More importantly, raising prices of surface water resources under such institutional arrangement will lead to more groundwater use due to the substitution relationship between surface water and groundwater resource. Saving surface water resources could be at the expense of overexploitation of more groundwater resources.

9.2 Policy implication

A number of recommendations for the future of irrigation pricing reform for water use efficiency and cost recovery in China are proposed according to our study.

First, it is clear that additional investment in measurement infrastructure would be necessary for volumetric pricing to be meaningfully introduced on a universal basis. Whether such investment is worth the costs is an open question, especially in the south.

Second, an improved understanding by farmers of their rights, how their water fees are used, and how irrigation finance actually works would likely go a long way towards both farmer willingness to pay volumetric water charges and the transparency, and therefore efficiency, of irrigation finance. A first step in this direction would be more meaningful opportunities for farmer involvement in irrigation decision making and more open accounting.

Third, any reform in surface water pricing needs to be made in the context of overall water management. For example, farmers in many regions have the opportunity to switch from surface to groundwater sources as surface irrigation prices rise. Unless groundwater is managed conjunctively with surface water under a single regime, surface water price reform may not result in increased water use efficiency or increased revenue for irrigation operation.

Fourth, when discussing full cost recovery, or even recovery of O&M, we must fully understand the basis for assessing those costs. While not examined in this study, it may be that full cost recovery is not feasible, or unreasonable, not only because irrigation water charges are "too low", but because project costs were too high. In some cases, high cost irrigation projects have been undertaken to provide larger social benefits, while in some others contentions have been made that construction and rehabilitation has been done without proper cost-benefit analysis. It is unfair to charge full cost recovery prices to farmers for projects designed to provide off-farm benefits or projects whose initial investment, in retrospect, turns out to be uneconomical.

Finally, because of the impacts of irrigation price increases on both production and income, additional policy measures will need to be put into place if government goals related to food security and rural income are to be met. These could be accomplished through a variety of means including additional investment in the agricultural sector, reduction in farmer taxation, or even subsidy.

While full cost recovery under volumetric pricing may be the ultimate goal, in the short to medium term partial reforms customized to the conditions of specific districts or regions may be more successful in moving towards the goals behind price reform. Irrigation districts in the south have limited infrastructure for volumetric facilities and are typified by small farms and relative water abundance. This makes continued water charging based on irrigated area a reasonable option. In such areas, relating irrigation water pricing reforms to other efforts to reduce supply costs and improve farmer and public participation in and/or information on water distribution and management as well as water fee accounting, collection and expenditure may be the most efficacious way to improve both water management and irrigation financing. In northern irrigation districts which are already most likely to have infrastructure for volumetric measurement, farm sizes are relatively large (by Chinese standards), and water scarcity is more of an issue, volumetric charging is a reasonable option. However, as in the south, its effectiveness for both water use efficiency and irrigation finance will depend on reform in field canal management, for example farmer participation in WUAs or related institutions. This could be especially effective if it resulted in irrigation water prices which were negotiated between irrigators and water providers based on water supply costs. But south or north, increasing water prices to meet full cost recovery is not practical in the short term, either for irrigation financing directly or for meeting larger policy goals related to production and equity. Charging irrigators for operation and maintenance is a realistic option for policymakers, especially if other reforms such as those discussed here are also put in place. But covering other costs still requires outside fiscal support.

ANNEX 1 WATER PRICING REGULATION FOR SURFACE WATER CONSERVANCY PROJECTS

Article 1 General principles

Section 1 On the basis of the Price Law and the Water Law of China, the regulation was carried out for the purpose of forming a sound water price mechanism of water supply projects, standardizing water price management of water conservancy projects, protection and rational development of water resources, improving water saving, and guaranteeing healthy development of the water resources industry.

Section 2 The scope of application of the regulation includes water pricing management of all water conservancy projects located in the PRC (People's Republic of China).

Section 3 Water prices of water conservancy projects in the regulation refers to the primary water prices on which, water managers taking water conservancy projects to block, store, grave or pump water, are based to sell water to water users.

Section 4 Water prices of water supply projects consist of water supply production costs, fees, benefits and taxation.

Water supply production costs refer to the direct salaries, direct material fees, other expenditure and the depreciation of fixed-capital, rehabilitations and water resources rents in the normal production procedures of water supply.

Water supply production fees refer to rational fees of selling, management and finance in the procedures of organizing and management of water production.

Profits, which are calculated on the ratio of net capital-profits, refer to the rational benefits that belong to the water managers, involving the normal water supply production.

Taxation, which is a component of the water price, refers to the amounts that the water managers should pay according to the national tax laws.

Section 5 Water prices are implemented in a uniform policy, but managed by different authorities at various levels of water supply projects. The implementation of different water prices of government directions or decisions should be according to specific conditions of different water conservancy projects. Water prices of water conservancy projects built and managed by the private sectors, but supported by governments, are determined on the directions of governments; Water prices of other water conservancy projects are determinated by the governments.

Article 2 The accounting principles and methods of water prices

Section 6 Water prices of water supply projects are accounted on the principles of rational recovering costs, rational profits, higher prices with high quantities and fair burden. Water prices are adjusted timely according to the situations of water production costs, water production fees, water supply and demand.

Section 7 Water prices of water supply projects in the same water supply regions, where the situation of water conservancy projects, geographic environments and water resources are similar are uniformly accounted. The specific scope of water supply is determinated by the provincial water administrative authorities, in consultation with the price administrative authorities. Water prices of other water supply projects are determinate according to their specific situations.

Section 8 The fixed-capital, costs and fees of water conservancy projects should be rationally shared and recovered among different functions of water supply, waterpower generation and floods protection. The shared costs and fees of water conservancy projects are recovered by water prices. The detailed methods of sharing and accounting are implemented according to the relevant regulations issued by the administrative authorities of finance, prices and water resources of the State Council.

Section 9 Water prices of these projects, built through loaning and bonds, should be made so that managers have the capability of recovering costs and fees, paying loan and bonds, and gaining rational profits during the managing periods, which refer to the economic life periods of water conservancy projects and are determinated by the weighted depreciation years, among different functions, according to the rules issued by the national financial administrative authorities.

Section 10 Water prices are determinated differently among different functions of water conservancy projects, according to the national economic policies and user's ability to pay. Water prices of water conservancy projects are classified into two categories, agricultural sector and non-agricultural sector, according to water users.

Water prices for agriculture refer to directly supplying water for grain production, cash crops production and aquatic production through water conservancy projects.

Water prices for the non-agricultural sectors refer to directly supplying water for industry, waterworks, generating waterpower and others.

Water prices for the agricultural sector are determinated on the principles of recovering water supply costs and fees, excluding profits and taxation. Water prices for the non-agricultural sectors are determinated on the basis of recovering water supply costs, fees and taxation, and certain profits according to the net capital of water supply. The ratio of net profits is determinated at more than 2 or 3 percent of the interest rates of domestic commercial banks.

Section 11 As for the prices of water for generating waterpower and returning for other utilizations of water conservancy projects, the water prices for generating waterpower (Yuan/CM) are determinated at 0.8 percent of the selling electricity prices (Yuan/KWH) of electricity networks of the waterpower stations. The prices of returning water for other utilizations are determinated lower than the levels regulated in Section 10. Water prices of water conservancy projects built only for generating waterpower are determinated at 1.6-2.4 percent of the selling electricity prices (Yuan/KWH) of electricity networks of the waterpower stations. Water prices of the water conservancy projects for the first power station, of the chain of power stations, are determinated on the principles above. Water prices of the second power station and the next power stations are reduced gradually.

Section 12 Water prices can be made 2-3 times higher than normal, under the abnormal situations of using the dead storage capacity of a reservoir.

Article 3 Water tariff approach

Section 13 Two-parts of water prices, cooperating with base prices and volumetric prices, should be gradually carried out for all water conservancy projects. The specific scope and procedures of implementation of a two-part tariff are specified by the provincial price administrative authorities.

The base prices are accounted on the principle of recovering the costs of salaries of staff, directly involved in water supply and management, and 50 percent for the depreciation and rehabilitation of fixed capital.

The volumetric prices are accounted on the principle of recovering the additional costs of water resources rent, material fees, other costs and fees, and profits and taxation.

Section 14 Water quotas management should be implemented in all sectors and increasing block rates of water prices should be adopted. The methods of increasing block rates are determinated by the administrative authorities of prices in consultation with the administrative authorities of water resources.

Section 15 Water prices of water conservancy projects, whose water sources are apt to be influenced by seasonal rainfall, can be carried out in the form of seasonal prices.

Article 4 The management scope of authorities

Section 16 Water prices of water conservancy projects, which are directly managed by the central governments or inter-provincial boundaries, are approved by the price administrative authorities of the State Council in consultation with the MWR.

Section 17 Water prices of water conservancy projects in localities are regulated by the provincial prices administrative authorities, in consultation with the provincial administrative authorities of water resources.

Section 18 Water prices of water conservancy projects listed on the categories of price-hearing-witnesses should be made on consideration of different opinions of various groups. Price-hearing-witnesses should be implemented during the process of the determination of water prices of the projects.

Article 5 Rights, duties and legal responsibilities

Section 19 When they apply for water pricing implementation or adjustments, water managers should provide, the files on water production, management, water costs, and other documents such as the accounts book, to the price administrative authorities.

Section 20 Volumetric water fees should be carried out. Of these, without carrying out volumetric water fees, the water managers should try their efforts to charge in volume. The price administrative authorities determinate water pricing rates, in consultation with the administrative authorities of water resources, for these projects without volumetric water facilities.

Base water prices are charged on the basis of water requirements of water users or the water supply capacity of water conservancy projects. Volumetric water prices are charged based on the water supply volume measured at the volumetric sites.

Section 21 Water pricing approaches should be open to the public. The managers of water and water users must be enforced to use water price policies and must not arbitrarily change water prices. Water managers or their authorized organizations and individuals have rights to collect water fees. Any other organization has no right to collect water fees.

Section 22 Water managers and users should sign a contract of water supply and use, according to the relevant national laws, regulations and water price policies. Except in cases where the contract is impossible to be fulfilled due to natural disasters, water managers should compensate for the losses of water users if they do not supply the required water to water users according to the contract.

Section 23 Water users should pay water fees timely, according to the relevant national regulations. Water users should pay for their violation of contract, according to regulations, if they do not pay timely. Water managers can cease to supply water for water users, under a legitimate process, if water users do not still pay water fees and the fees for violating the treaty after the limited period of water managers' notice.

Section 24 Any organization or individual must not violate water pricing regulations, for arbitrarily increasing or decreasing water fees in any name. Any organization or individual is strictly prohibited from withholding and embezzling water fees.

Section 25 The price administrative authorities of governments, at various levels, should supervise the execution of water prices of water conservancy projects. Organizations or individuals breaking price regulations or policies must be punished, according to the Price Law and the Administrative Disciplinary Measures of Breaking Price Law.

Article 6 The annex

Section 26 Water fees of water conservancy projects is a kind of managing of profit obtained by the water managers through water supply production. The expenditure and management of water fees should abide by the financial and accounting rules issued by the administrative authorities of finance and water resources of the State Council.

Section 27 The management departments of drainage projects, with definite beneficiaries, except for farmers, can collect drainage fees from the beneficiaries. The charge level is accounted by the price administrative authorities, on the principle that it is lower than water price to supply. Drainage fees and water supply fees should be separately accounted and collected, for the water conservancy projects, with functions of both water supply and drainage.

Section 28 The provincial administrative authorities of goods prices have rights to issue specific regulations in consultation with the provincial administrative authorities of water resources for tailoring the regulation to the local conditions, but they should report the local regulations to the relevant authorities of the State Council for records.

Section 29 The regulation is formally implemented from January 1 2004. Items in the regulations before, which are contravening the regulation, are invalid.

Section 30 The administrative authorities of prices and water resources of the State Council are responsible for the explanations.

ANNEX 2 LOCATION OF THE SURVEYED IRRIGATION DISTRICTS

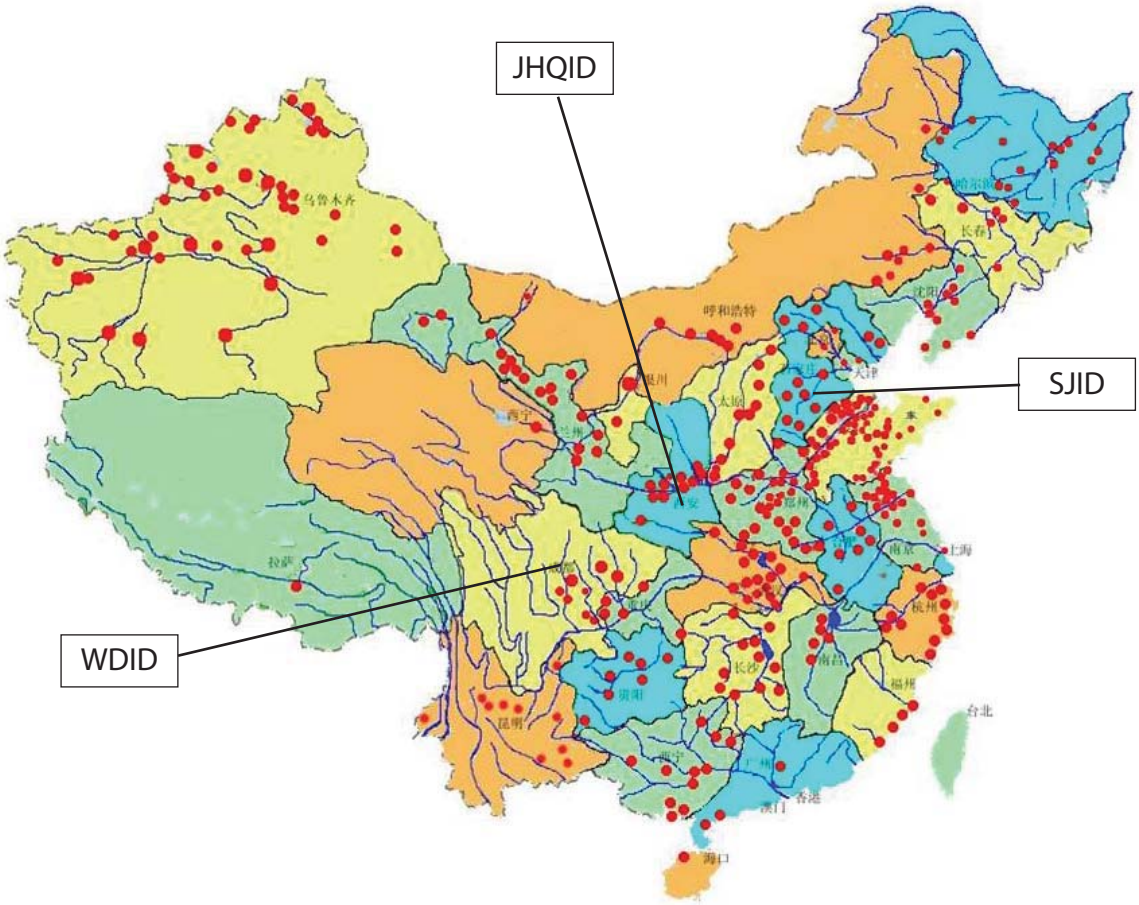


Figure A1. The location map of the Wudu irrigation district.

Figure A2. The map of the Wudu irrigation district.

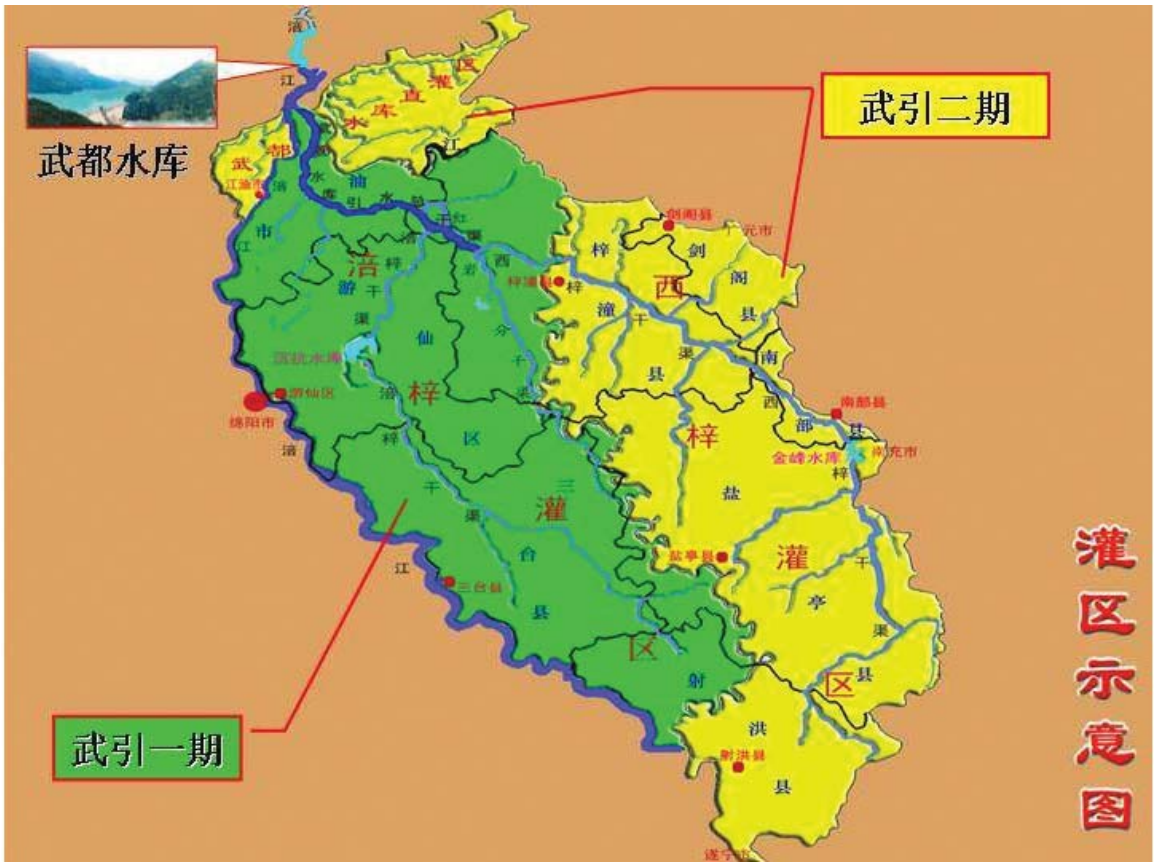


Figure A3. The map of the Jinghuiqu irrigation district.

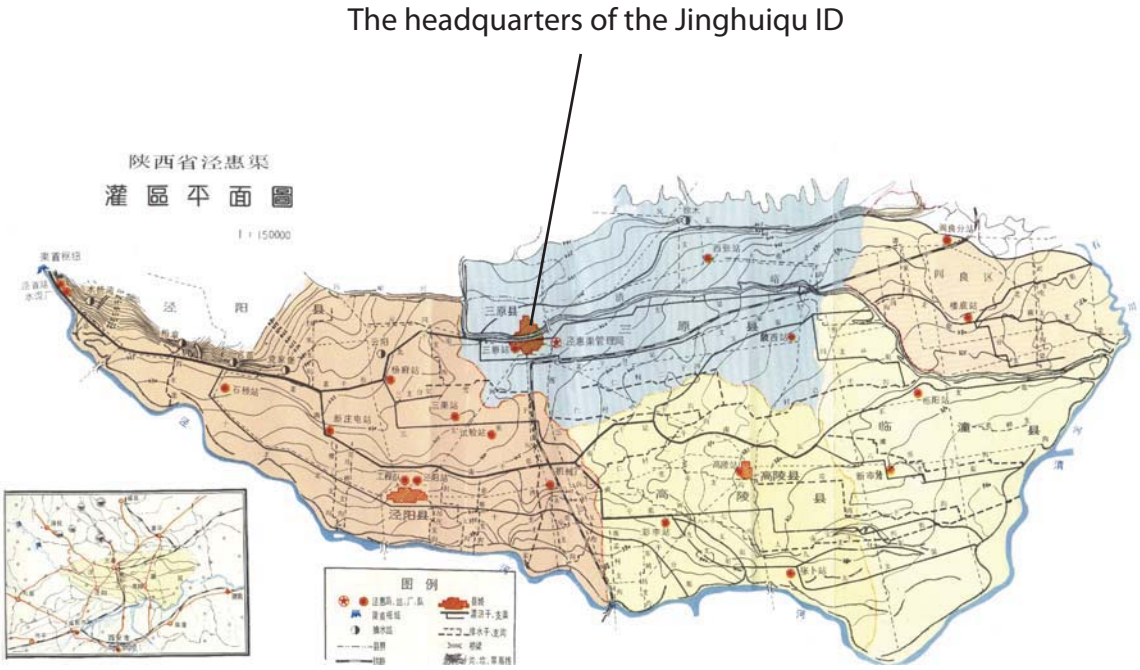
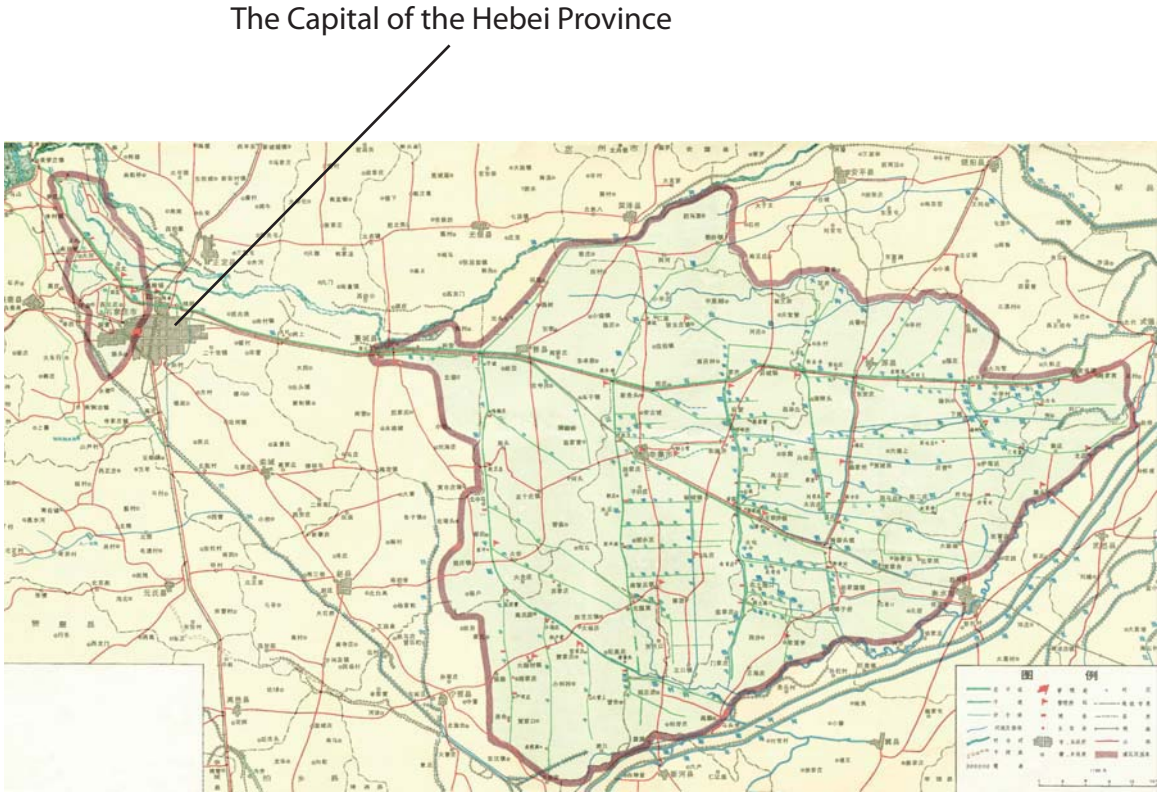


Figure A4. The map of the Shijin irrigation distric.



ANNEX 3 QUESTIONNAIRES

ID	
Province	
County	
Township	
Village	
Address	
Post code	

	Village Table	Surface Water Table	Groundwater Table	Household Table
Enumerator				
Date				

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