The changing nature of irrigation in northern China: Assessing the impacts of fiscal decentralization on village-level irrigation development

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A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of City and Regional Planning.

Chapel Hill
2011

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ABSTRACT

CHRISTINE E. BOYLE**:** The changing nature of irrigation development in Northern China: An examination of the impacts of fiscal structure on village-level irrigation provision
(Under the direction of Dr. Yan Song)

In recent decades, debate over how to promote water conservation in irrigation has increased as water has become scarcer and competition for water has increased – between neighboring locales, between farms and cities, and between people and their environment. The irrigation debate is particularly salient as agricultural water use is directly tied to food production and rural livelihoods in many of the world's poorest communities. Despite widespread reforms to promote irrigation efficiency and large influxes of infrastructure investment to improve water distribution, China's record for increasing irrigation-related water conservation and alleviating poverty, without disrupting agricultural production, remains poor.

This dissertation examines local irrigation infrastructure provision processes to better understand how China's decentralized fiscal structure impacts regional irrigation development distribution and on-the-ground irrigation system performance. This is accomplished by investigating the case of northern China where roughly 42% of the nation's population lives, 250 million small plot farms operate, yet where water availability is only 757 cubic meters per capita, about one-tenth of the world average. To unfold the relationship among investment, fiscal structure and irrigation performance, this dissertation uses descriptive and multivariate analysis of a panel data set for seventy villages in northern China to track irrigation investment patterns and outcomes over a ten-year period. Analysis reveals that despite increasing amounts of investment overall, irrigation provision disparity between villages in northern China is growing. Further, analysis of the determinants of village irrigation investment portfolios indicates that water shortages do influence farmer investment behavior and upper-level government targeting for investment funds. Results further reveal a shift in the locus of decision making over village-level irrigation projects in recent years, from village level decision making, to irrigation districts and county-level water resource bureau agencies' direct involvement in village irrigation development. This re-concentration of fiscal decision making has many implications for regional irrigation coordination, poverty alleviation and northern China's precarious water resource future.

DEDICATION

I dedicate this dissertation to Sandy and Ozzie,

for teaching me to how to reach up and touch the sky.

ACKNOWLEDGEMENTS

Many people have contributed to this dissertation and when they say it takes a village, I always imagine they are speaking of dissertations. Nonetheless, the work is original and all errors of omission and commission are my own.

The members of my dissertation committee convened from across the United States have been my most stalwart advocates. This study is the product of their intellectual guidance and their combined influence is evident on every page. My advisor, Yan Song, gave me an open door to pursue this topic from an interdisciplinary angle, and encouraged me to overcome the scholarly and logistic hurdles such an approach presented. She dispensed invaluable advice and provided the freedom to develop what indeed turned out to be an interdisciplinary work. Meenu Tewari greatly influenced my approach to studying international development and introduced me to organizations and the notion of following the flows of funds to uncover organizational patterns. Her careful guidance to keep unraveling the problem in order to uncover hidden pockets of truth contributed to my understanding of the depth required to produce good research. Phil Berke was an unerring advocate for pursuing my research and fulfilling my potential as a researcher. His dedication to students, teaching and developing sustainable paths for development provided great inspiration for this work. I am grateful to all committee members for their generosity in time and guidance, and for challenging me to rise to this occasion.

This dissertation would not be possible without the enduring partnership I developed with Dr. Jinxia Wang and the researchers and staff at the Center for Chinese Agricultural Policy (CCAP). When I first read the works of Dr. Wang, Scott Rozelle and the CCAP researchers, I felt compelled to understand more about how irrigation works in rural China. Without Dr. Wang having recognized my commitment and dedication to this research back in 2006, and allowing me to join the field work team, my work in this area would not have been possible. Her patience and relentless pursuit of good data in difficult field conditions made possible a body of work on irrigation development in North China that otherwise would not exist. The lead field researcher Lijuan Zhang and her team of enumerators sacrificed sleep, regular meals and comfort to help bring this work to the world, while patiently handling my constant stream of questions about what I observed in the field. My deep gratitude to the entire CCAP team for allowing me to access the fascinating world of village-life in modern day China.

Friends and colleagues in China provided encouragement and welcome respite from the rigors of conducting field work. I am indebted to Julian Wong, Jane Hayward, Dana Powell, Jia Ching Chen, Maggie Clinton and Leslie Tai for lending me their ears and many delicious Chinese meals during my 2006 and 2008 stays in China. Elsewhere, I am extremely grateful to my City and Regional Planning colleagues in Chapel Hill, NC for following the evolution of this project and making countless valuable suggestions along the way. Mary Donegan, Tab Combs, Tracy Hadden Loh**,** Gihyoug Cho and Danielle Spurlock each sat through numerous practice presentations and provided candid and much needed clarity on my study, and lunches and beers when needed. I would also like to thank Carolyn Turner, Shannon Brownfield and Udo Reisinger for their patient and helpful administrative assistance at every critical stage.

Along the way my Chapel Hill family including Chris Norman, Kate Shallcross, Kate Baylor, Marci Lew, Anna Schurmann and Lisa Parker created a community of love and support necessary to carry a PhD student through the ups and downs of dissertation writing. Whenever I was in need, I didn’t have to go far to find a warm home, a supportive ear and a friendly tennis court waiting to burn off any dissertation blues. I especially thank André Abouta for humanizing the final stages of my graduate school career. He offered much needed perspective and tolerated long absences with considerable grace. His love of learning and dedication to realizing each of our greatest human potential reminded me why I engaged in this process.

I benefitted from many generous institutional sponsors. The UNC Global Center supported my early musings though the CV Starr Grant and the Pre-dissertation Travel award. The National Science Foundation’s East Asia and Pacific Summer Institute provided me placement at CCAP and funding for my first foray into exploring China’s irrigation development. The US Fulbright Foundation provided support for conducting my field work and nine months of data cleaning and work at CCAP in Beijing. I am thankful again to CCAP for providing me academic peers, a working space and an institutional base in China.

Several mentors have been integral to my professional and scholarly development. Professor Karen Polenske at MIT provided invaluable coaching and guidance as I reached the latter stages of my PhD career and encouraged me to pursue research and also become a good teacher to leave a legacy for generations to come. Professor Wendy Wolford, now at Cornell University, introduced me to the world of ethnography and qualitative research methods. Her belief in understanding people's stories and providing voices to people who otherwise would go unheard helped me to ground my research in people's experiences. I am thankful to her for her time and encouragement as I developed many versions of proposals and ideas, which she gracefully encouraged me to pursue. Another person instrumental to showing me the various paths available for researchers is Dr. Noel Greis. Between her frequent trips to China and successful running of a research center, she always found time to meet and catch up on my latest career and research ideas. Each of these mentors has provided guidance through their encouraging words, but equally through their examples in the professional world of research.

This dissertation would not have been possible without the unwavering support of the Boyle family. My parents taught me from a young age to ask questions and not be afraid to learn the answers. These lessons served me well as a researcher. My wonderful siblings Traci, Brandon and Laurie have stood by my side throughout my academic career. From visits to Beijing in the dead of the Beijing Winter, to autumn time visits to Chapel Hill, my family has supported me despite not understanding exactly what it was that had captured my imagination, and indeed my life over these past six years. I thank each of you for your support over all these years.

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LIST OF ABBREVIATIONS

2SLS	2-stage least squared
CCAP	Center for Chinese Agricultural Policy
HRS	Household Responsibility System
ID	Irrigation District
IVs	Instrumental variables
NCIM	North China Irrigation Management Survey
WUAs	Water User Associations

Chapter 1: Introduction: How fiscal decentralization impacts irrigation development in northern China

1.1. Background[1]

1.1.1. Irrigation development in China struggles to achieve its goals

In recent decades, debate over how to promote water conservation in irrigation has increased as water has become scarcer and competition for it has increased – between neighboring locales, between farms and cities, and between people and their environment. The irrigation debate is particularly salient as agricultural water use is tied directly to food production and rural livelihoods in many of the world's poorest communities. Despite widespread reforms to promote irrigation efficiency and large influxes of infrastructure to improve water distribution, China's record for increasing irrigation-related water conservation and alleviating poverty, without disrupting agricultural production, remains poor (Huang, Dawe et al. 2005).

[1] This dissertation has IRB approval (Study #: 08-2072).

Irrigation in China remains a relatively low technology and low efficiency operation (Blanke, Rozelle et al. 2007). Households typically cultivate a few small plots of land and use traditional irrigation techniques such as flood irrigation and burrowing (Blanke, Rozelle et al. 2007). In the past thirty years the government has worked to expand irrigated arable land in order to boost yields and rural incomes (Huang, Rozelle et al. 2006), yet several observers of China's agricultural development doubt the ability of the current system to service this increased irrigated area due to decreasing water availability (Zhu, Giordano et al. 2004) and others express doubt that the irrigated land expansion will contribute to increases in agricultural yields (Hu, Huang et al. 2000).

1.1.2. Shifts in fiscal policy impact irrigation

Understanding recent irrigation policy in China requires looking at the increasingly decentralized structure of China's irrigation infrastructure provision. In the early 1980s the Chinese central government began experimenting with decentralized fiscal policy by creating arrangements that changed the rules for how locally collected revenues were shared with the central government (Oksenberg and Tong 1991)[2]. Under reform, local governments gained greater discretion and flexibility in deciding how to generate revenue and make expenditures (Oi 1992). The effects of these policy shifts on irrigation are observed in the form of increased

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[2] A large literature on fiscal policy in China exists and categorizes the many different revenue sharing forms, and the impacts of such agreements in the post-reform era. For much more detailed look at China's fiscal contracting, extra budgetary revenue structure, and other experimental fiscal policies see: Oksenberg and Tong (1991),Wong (1991), Oi (1992), West (1995), Jin et al (2005), Lin and Liu (2000), Tsui and Wang (2004), Whiting (2007).

local investment and irrigation infrastructure planning (Lohmar, Wang et al. 2003; Fan, Zhang et al. 2004).

Local responsibility over irrigation development, as opposed to centrally planned systems, changes how projects are planned, funded, built and maintained. First, local irrigation development goals are often different than upper-level government goals (Ostrom 1991; Uphoff 1991). For example, local governments and farmers are interested in securing more water for crops and less interested in regional water cooperation and conservation. Next, local governments have very limited funds available for public works projects such as irrigation development. Particularly given the high upfront capital costs for canal construction, many local governments lack the revenue sources to cover such costs. Next, given irrigation networks classification as common pool goods, when local governments are unable to provide irrigation works, systems often fall into disrepair[3]. On the other hand, when irrigation systems are locally funded and built, studies show increased feeling of ownership and responsibility over the infrastructure leads to better maintenance of the canals (Coward 1986). For these reasons, impacts of decentralized fiscal policy go beyond the flow of funds and directly impact how irrigation systems are built and maintained.

Overall in China, local and central government investment into irrigation in 2000 exceeded 35 billion Yuan (USD $5.1 billion) (MWR 2000-2008), indicating a

3 An underlying explanation for the difficulty in developing well-managed local irrigation systems relates to the specific characteristics of irrigation systems as common pool resources Ostrom, E. (1991). Governing the commons : the evolution of institutions for collective action. New York Cambridge University Press. The two primary problems associated with common-pool goods are: (1) the overuse of the good where one person's use subtracts from benefits available to others; and (2) the free rider problem where excluding others from gaining the benefits of use of the good is costly and difficult to monitor. These problems pose specific difficulties for irrigation planners and managers looking to develop fair and equitable irrigation systems.

strong commitment to improving irrigation systems. However, despite massive influxes of irrigation investment, agricultural water use in China is inefficient by global standards. A recent study found that due to the poor management of the nation's canal network, only 53 percent of water from primary canals is actually delivered to the field (Cai 2010). Given the resolve of China's leadership to promote water conservation, it remains unclear how best to improve rural irrigation performance given the complex set of incentives faced by localities tasked with irrigation infrastructure development. Unraveling the relationship between decentralized irrigation provision and irrigation outcomes will aid in crafting policies that work to achieve China's irrigation policy goals.

1.2 Study Justification: How fiscal decentralization explains irrigation development outcomes

This section makes explicit the relationship between fiscal decentralization and irrigation development. This is accomplished first by defining fiscal decentralization, then defining irrigation development and its policy outcomes, and finally by describing the overlap between an institutional structure (fiscal decentralization) and a function of decentralized water management policy (irrigation development). Finally, this section presents how this dissertation will examine the crossroads of fiscal policy and irrigation development.

1.2.1 Define fiscal decentralization

This study draws on the public economics literature, based in the Wicksellian orientation of public finance and fiscal decentralization (Wicksell 1977). Under this tradition, the state is not treated as an exogenous force that perfects the outcomes of the market economy. Instead fiscal analysis is based in the assumption that "the actual fiscal conduct of the state emerges through complex interactions among fiscal and political participants, and the precise character of those interactions is constrained and shaped by a governing institution and constitutional framework" (page 10) (Backhaus and Wagner 2005). Using this analytical framework, fiscal structure is defined as the composition of government expenditure and the structure of taxation and public revenue generation. Fiscal decentralization is defined as the devolution by central (i.e. national) government of specific functions to local (i.e. province or municipal) governments that are independent of the center.

Fiscal decentralization arose as a popular institution across the developing world in the 1980s and 1990 under the reasoning that decentralization can make government more responsive to the governed by "tailoring levels of consumption to the preferences of smaller, more homogeneous groups" (Wallis and Oates 1988). Fiscal decentralization is theorized to promote economic vitality by providing sub-national (province, county, township or village) governments' authority to make local public investment decisions based upon what is in need by that locality. The academic literature on decentralized fiscal policy argues that greater flexibility on the part of the localities, given appropriate controls by the state, tends to be superior fiscal policy (Foster and Rosenzweig 2001; Faguet 2002); however China-specific literature contends that decentralization has resulted in increasing regional disparities and under-provision of public goods in rural areas (Zhang 2006).

The previous two decades have seen shifts in China's fiscal structure. Important developments, to be discussed more in depth in later chapters, include: 1) alterations in the distribution of revenue sources (for example, shifts in revenue-sharing agreements between province and center, and down the hierarchy); 2) vertical shifts in the locus of responsibility for certain functions from localities to counties and townships (as a consequence of the 2002 tax-for-fee reforms); and 3) horizontal changes in the structuring of local governance responsibilities (such as the creation of special purpose agencies for the delivery of local services in response to local government's lack of public funds). The implications of these changes represent an important area of study in understanding irrigation governance at the regional and local level. With these policy shifts come changes in the responsiveness of government and in the distribution of services and benefits conferred to villages and farmers.

1.2.2. Define irrigation development

In the past twenty years, irrigation development has increasingly been considered a social-technical sector, with organizational and technical factors considered equally important in improving system performance as the physical and engineering facets of irrigation systems (Uphoff 1991, Ostrom 1990). While farmer participation continues to receive considerable attention by scholars and policy makers concerned with improving irrigation system outcomes (Uphoff 1986; Parlin and Lusk 1991; Ostrom 1992; Lin 2003; Ou, Zachernuk et al. 2004), how farmers, contractors, village collectives and government agencies' work together to manage and invest into irrigated areas has not received much attention by researchers, apart from acknowledging that the relationship between farmers and upper-level agencies needs to be better understood (Agrawal 2002).

This study uses the term ‘irrigation development’ to refer to both improving the performance of existing irrigation systems and also to expanding irrigation service to previously non-irrigated areas. Irrigation development thus includes responsibilities of operations and maintenance, in addition to construction activities which establish new irrigated area. The particular facet of village-level irrigation development this dissertation investigates is the upgrading and construction of surface water infrastructure such as canals, pumps, measuring devices, sluice gates, and diesel generators (for pumping water uphill). Such infrastructure provides the ‘bones” of an irrigation system, around which other operational activities occur, including fee collection, delivery scheduling, and maintenance. The structural, management and operational elements together comprise a village’s irrigation system.

Infrastructure provision and planning is a controversial budgetary activity for every village in China, involving coordinated decision making, tight budget constraints, and potentially uneven distribution of benefits (i.e. which sections of the village get lined canals, new control gates, etc). How such budgetary decisions are made, and what entity makes such decisions, have been found to impact the outcomes of projects in terms of: villagers’ sense of ownership and desire to maintain the infrastructure (Coward 1986); how projects suit the ecological and social needs of the community (Uphoff 1991); and lastly, if the community has the local capacity to operate and maintain the infrastructure component, i.e. high tech drip irrigation systems (Blanke, Rozelle et al. 2007). The outcomes of irrigation infrastructure development, although only one aspect of a local irrigation system, have been found to contribute to reducing villages' poverty levels (Huang, Rozelle et al. 2006) and to spur economic development (Fan 2002).

Presuming that even the technical aspects of surface water irrigation development -- such as canal design, reliance on pumps, purchasing decisions over diesel generators, canal lining material and other equipment – are made within an underlying organizational framework, a more systematic analysis of fiscal management related to irrigation infrastructure provision is needed. This analysis examines the structure, functions and outcomes of upper-level agencies, local irrigation managers and farmers responsible for irrigation system operations and development. The organizational structure used to unpack these relationships is a fiscal decentralization framework, where the study measures how degrees of fiscal decentralization shift over time.

1.2.3. How fiscal decentralization explains irrigation development outcomes

Given the need to understand more clearly how the impact of localized policy making and planning on irrigation development and performance, one way to accomplish this is by tracking and analyzing local irrigation development in a place with different levels of hierarchy involved in irrigation development. The degree of decentralization can be assessed in two ways: 1) by examining composition of funds for developing local irrigation systems and 2) examining the degree of decision making autonomy over irrigation project funding held by local irrigation managers and upper-level irrigation agencies. The impact of fiscal decentralization on irrigation development can be evaluated by looking at how variation in degrees of fiscal decentralization results in different outcomes including: distribution of irrigation investment, water conservation, crop yields and farmer incomes.

A broad literature on organizations and institutions across disciplines asserts that the internal structure of institutions matter for development (DiMaggio 1991; Ostrom 1991; Krishna 2002). Across these literatures, organizations and the intermediary forces affecting outcomes, differ widely. The theme tying together the disparate organizational theories is that underlying processes, not tied to rational behavior, explain organizational variation. For the purposes of this dissertation one particular set of underlying processes is examined, that is, decision making around flows and channels of revenues and spending, or fiscal structure. Fiscal structure is one element of local government organization and one that has yet to be investigated for the case of irrigation provision, particularly in water scarce locales.

Why is fiscal structure critical to understanding local irrigation development? How fiscal decisions are made has profound consequences over all aspects of a given project's outcome, not limited to: what is built, how it is built, where it is built, who are the primary beneficiaries (and who are not), and ongoing maintenance and operation of the facility. The interplay of public and private investment, and the underlying decision-making processes over allocation of budgetary funds, comprise a village's fiscal structure for irrigation provision.

As villages have become more financially self-sufficient (Oi 1992; Wong 1997) following a series of decentralization policies enacted during the post-reform era, villages often lack requisite capital resources to provide public goods, including irrigation infrastructure (Fan, Zhang et al. 2002; Tsai 2007). In addition, village-level investment portfolios have become more diverse than in pre-economic-reform. However, despite fiscal constraints, local irrigation investment activity in China continues to increase, yet there is little understanding as to the channels impacts of village-level public and private investment activity.

The main hypothesis put forth in this dissertation is that fiscal policy structure influences distribution and outcomes of irrigation development. Examining the diversity of fiscal policy structures within China's rural villages will aid in understanding successes and failures in China's irrigation development. By paying heed to both village-level fiscal phenomena as well as institutional structures surrounding these phenomena, this study contributes to explaining obstacles to improving village-level irrigation management that are up to now, undocumented for northern China.

1.3. Research objectives and questions

This dissertation aims to examine how local fiscal policy impacts the channels and outcomes of village-level irrigation infrastructure provision in northern China between 1998 and 2008. Further, this dissertation aims to contribute to explaining how a strong over-arching bureaucracy impacts local irrigation development outcomes and how water scarcity drives private investment behavior.

Using village-level surface water management panel data sets collected by the Center for Chinese Agricultural Policy (CCAP), this study examines two facets of irrigation provision, (1) the channels and magnitudes of village-level investment across the sample villages, and (2) how local authority over irrigation funding impacts irrigation development outcomes. These analyses will be carried out using descriptive statistics and multivariate analysis to examine irrigation investment into 70 villages in northern China.

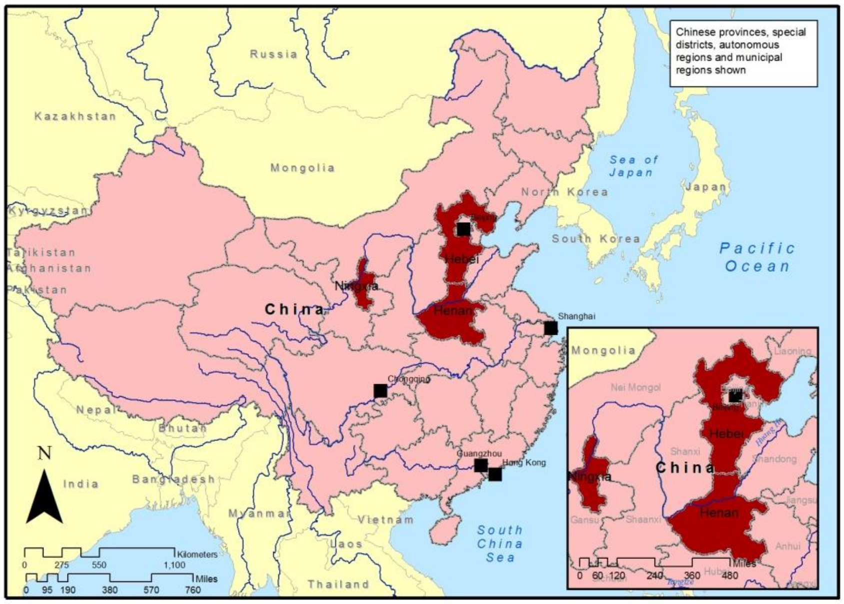
This dissertation examines two primary questions related to the above stated objectives:

1) Examine channels of investment: What incentives drive different sources to invest in village-level irrigation development?

2) Examine how fiscal decentralization impacts irrigation development outcomes: How does the degree of local fiscal authority over irrigation revenue and spending impact village-level irrigation system performance?

To analyze these questions, this study uses village-level survey data from three provinces in northern China (Hebei, Henan, and Ningxia -- see Figure 1 for a map of the study area) dating between 1998 and 2008. Within this dataset, and during the author's time in the field in northern China, variation was observed across villages and over time in irrigation investments, decision-making structures, projects types and water-resource conditions, leading to formulation of research questions to assess how flows of funds and irrigation outcomes have changed in China over the 10-year study period.

Figure 1 Map of China with study area darkened



1.4. Placing the study: Irrigation and fiscal decentralization in modern China

This dissertation examines local irrigation infrastructure provision processes to better understand how China's decentralized fiscal structure impacts regional irrigation development distribution and on-the-ground irrigation system performance. This is accomplished by investigating the case of northern China where roughly 42% of the nation's population lives, 250 million small plot farms operate, yet where water availability is only 757 m^3 per capita, about one-tenth of the world average (World.Bank 2009). Northern China, known as the 'bread basket of China' also produces about 25% of China's grain (McKinsey 2009). Recent droughts have affected 21 million hectares of crops and brought attention to the need to improve irrigation efficiency in order to maintain the nation's food security.

Modern China presents a vivid and compelling case through which to examine fiscal and organizational aspects of irrigation development for several reasons. First, despite widespread reforms to promote irrigation efficiency and large influxes of infrastructure investment to improve water distribution, China's record for improving irrigation-related water conservation and alleviating poverty, without disrupting agricultural production, remains poor. Second, despite a record of poor performance, investment into irrigation development is relatively high, and comes to the village through multiple channels, including government agencies, village collectives, contractors and farmers. Next, the political structure of village-level irrigation governance has shifted numerous times over the last 30 years -- from a highly centralized system, to complete fiscal decentralization, and more recently, to a re-concentration of fiscal authority over public projects at a regional level. This variation allows both for a rich research design framework and an interesting story of how fiscal reform affects natural resource utilization. Lastly, enduring water shortages in the study region, northern China, allow one to scrutinize irrigation investment, in response to changing water resource conditions. Such crossroads create an interesting and useful case for examining environmental infrastructure planning.

Amidst the numerous political, fiscal, agricultural and land use changes occurring in northern China, this dissertation aims to probe a small aspect of these colossal shifts. Digging deeper into the issues of water scarcity, food production and infrastructure provision decision making, this dissertation expands understanding of land-society-natural resource interactions, in northern China and in other arid regions of the world, by untangling the relationship between infrastructure investment, water resource scarcity and local fiscal authority.

1.5. Précis

This dissertation is organized as follows. Chapter 2 presents the conceptual framework for the dissertation, as well as introducing the data and sample for the study. Chapter 3 tracks the history of irrigation investment for surface water irrigation infrastructure in northern China using data over a 25-year period. The chapter first builds a timeline of policy events affecting irrigation development during the study period. Next, chapter 3 empirically analyzes surface water irrigation infrastructure investment in 70 villages in northern China between the years 1981 and 2008. Chapter 4 reviews the literature on the determinants of investment, and then uses multivariate analysis to examine the determinants of village-level surface water irrigation infrastructure channels of investment for the sample villages. The determinants analysis investigates the targeting and demand side determinants of investment sources. Drivers of private investment into surface water irrigation development are also examined. Measures of investment, targeting and demand side factors are described in detail. Chapter 5 analyzes impacts of localized authority on irrigation development outcomes. This chapter begins by reviewing the literature on center local decision making for water-resource related infrastructures. Measures of local revenue authority, water planning authority and irrigation development outcomes are described. Next, the chapter uses multivariate analysis to examine how varying levels of local revenue authority over irrigation revenue and spending impact irrigation system performance. The study uses several measures of revenue authority to examine how local fiscal policy structure on irrigation outcomes in northern China. Chapter 6 reviews major findings and ties findings to larger policy questions around irrigation, fiscal policy and rural development. It concludes by reviewing this dissertation's key theoretical contributions and directs for future research.

Chapter 2: Conceptual Framework: Linking theories of decentralization to irrigation development

2.1. Introduction

This chapter presents a conceptual framework to assess whether and how decentralization affects irrigation development and to answer the research questions posed in chapter 1. Two particular aspects of decentralization are examined using village-level irrigation infrastructure investment as a means of assessing levels and impacts of decentralization on irrigation development. First, diversity in village-level irrigation investment portfolios is considered an indicator of fiscal decentralization. Chapter 4 explores how different incentives drive diverse funding channels and investment levels into village-level irrigation investment portfolios. Second, varying levels of irrigation revenue and spending authority to make irrigation investments are considered a form of China's fiscal decentralization structures. Village-level irrigation revenue and spending authority are used to assess how decentralized fiscal and water planning authority impact specific irrigation development objectives, including water conservation, increasing crop yields and increasing farmer incomes. These two facets of decentralization, drivers of diverse channels of investment and impacts of revenue and spending authority on irrigation development, provide the backbone of the two conceptual frameworks that will guide this dissertation.

This chapter is divided into five parts. The first part presents the empirical framework guiding this study, examination of village-level irrigation infrastructure investment channels and development decision making authority. The second part presents an conceptual that specifies the relationships among variables used in analyses in chapters 4 and 5. The third part introduces the northern China study area. The next part describes the data used for this study including the population, sample and survey instruments used for the study. A summary concludes the chapter.

2.2. A "bottom up" analytical approach

The 2 conceptual frameworks presented in this paper are unique within the fiscal policy and irrigation development studies as they are neither province-level studies of fiscal decentralization, nor are they case studies of 1-2 villages, as fills the irrigation development literature. Instead, this paper uses a village –level perspective to examine the crossroads of fiscal policy and irrigation development for northern China in 70 villages over a 10-year time period. Irrigation development is viewed from the basic building block of rural Chinese society, the village, and a number of different conceptual dimensions are presented to examine fiscal structures present in northern China and the impacts of local fiscal authority on irrigation outcomes, as tracked in these 70 villages and reported by village leaders and surface water irrigation managers.

In order to understand how and why fiscal decentralization impacts local irrigation development outcomes across northern China, this study focuses upon the most basic unit of governance in rural China, the village. Although field-level practices offer insight into agricultural water use practices and agricultural productivity, this study takes a step back, or a step up in this case, to view the larger institutions around on-field irrigation infrastructure investment, that is the village. Doing so allows viewing on-field practices as a set of behaviors nested within the larger irrigation bureaucracy, following in the tradition of organizational theorists Granovetter and Dimaggio (Granovetter 1985; DiMaggio 1991). Further, given the characteristics of surface water irrigation systems as a common pool resource, defined as “a valued natural or human made resource facility that (are) available to more than one person and subject to degradation as a result of overuse” (Ostrom 1991), studying irrigation provision at the individual level leaves out important issues of coordination, public and private investment decision making, interactions with the bureaucracy, and other contextual factors necessary to understand a village’s irrigation development story. Province and regional-level studies also fail to locate the bulk of irrigation planning decision making, which often takes place within the village itself.

In China, the nexus of local power is the village administration (leader, party secretary, irrigation manager). From the grassroots (village) level, one can observe how funds flow and policy decisions channel their way to the village. Policy and investment decisions often wind down the bureaucratic hierarchy, from the State Council, to the province, county, township, and finally, to the village. Implementation of policy and investment priorities at the local level in China has created a wide range of on-the-ground investment frameworks for irrigation system development. Understanding how village fiscal decisions are made, and how this relates to the larger regional, village and irrigation system operations, is the basis for this unique view of irrigation development in China. This dissertation uses survey data collected at three points in time (2001, 2004, and 2008), for seventy villages in northern China representing a wide range of local fiscal policy arrangements for surface water irrigation infrastructure provision. In doing so, this study uses an inductive approach to assess fiscal decentralization in China and how decentralization policies impact irrigation development.

While villages in this study are located in different parts of northern China, the physical structure of canal systems in each irrigation district (ID) and their organization are similar. Each ID has a set of main canals that take their water directly out of the Yellow or Hai Rivers, which run west to east across north and northeast China (refer to Figure 1 for a map of the region). Officials from the ID, depending on their allocations from the regional Water Resource Bureau, or Yellow River Basin Commission, make up a water allocation plan for each village. In most of the study IDs, there is a metered gate that supplies water to each village. This makes each village more or less an independent agent of the ID. Such arrangements are typical of villages in northern China next to the Yellow River. The canal network in the village, then, is completely maintained by the village and all of the water that flows into the village is for the exclusive use of the village's own residents (and does not have to be shared with villages either up or down stream). In each village, there is always one person – whether leader or appointed water manager – that is responsible for coordinating water deliveries from the IDs and remittances of water fees from the village.

2.2.1. Decentralized fiscal policy as a factor hypothesized to impact village-level irrigation investment channels and outcomes

Based on reviews of the determinants of irrigation investment literature and impacts of fiscal decentralization literatures (found in chapters 4 and 5 respectively), decentralized fiscal policy is hypothesized to impact irrigation development in two ways. First, through diversifying of the channels of irrigation investment in China's villages. Second, through variation in degrees of authority over fiscal decision making for village irrigation development investments. Although the literature, hypotheses, measures and models will be presented in the analytical chapters 4 and 5, it is useful at this early point in the dissertation to introduce the basic conceptual frameworks providing the backbone for this study.

2.2.2. Conceptual Frameworks

This section presents and describes two separate conceptual frameworks. This first conceptualizes the analysis found in chapter 4, assessing how incentives from different funding sources drive levels of investment. The second conceptualizes the analysis found in chapter 5, assessing the impact of local fiscal and water planning authority on irrigation development outcomes.

2.2.2.1. <u>Drivers of irrigation investment</u>

Based on literature reviewed in Chapter 4 of this dissertation, this study hypothesizes that the three main funding sources contributing to irrigation investment in China villages – upper-level government agencies, the village collective and farmers – each have separate incentives driving how much money they invest into a village's irrigation investment infrastructure. In summary of the literature review in chapter 4, while upper-level governments investments are driven by aims to reduce disparity and provide high cost public goods to promote private sector productivity (Aschauer 1989), public investment by local governments is driven by accountability of leaders and local economic base (Zhang, Fan et al. 2004). Private investment is driven by an incentive to avoid water resource uncertainty to make revenue from higher value crops.

The measurement of decentralization in this analysis is village -level irrigation investment composition by multiple sources. Three separate measures of irrigation investment are considered: 1) total magnitude of investment from all sources; 2) share of investment from upper-level government and village collective; and 3) the presence of farmer investment in the village.

Figure 2 Conceptual model for determinants of village irrigation investment from diverse funding sources

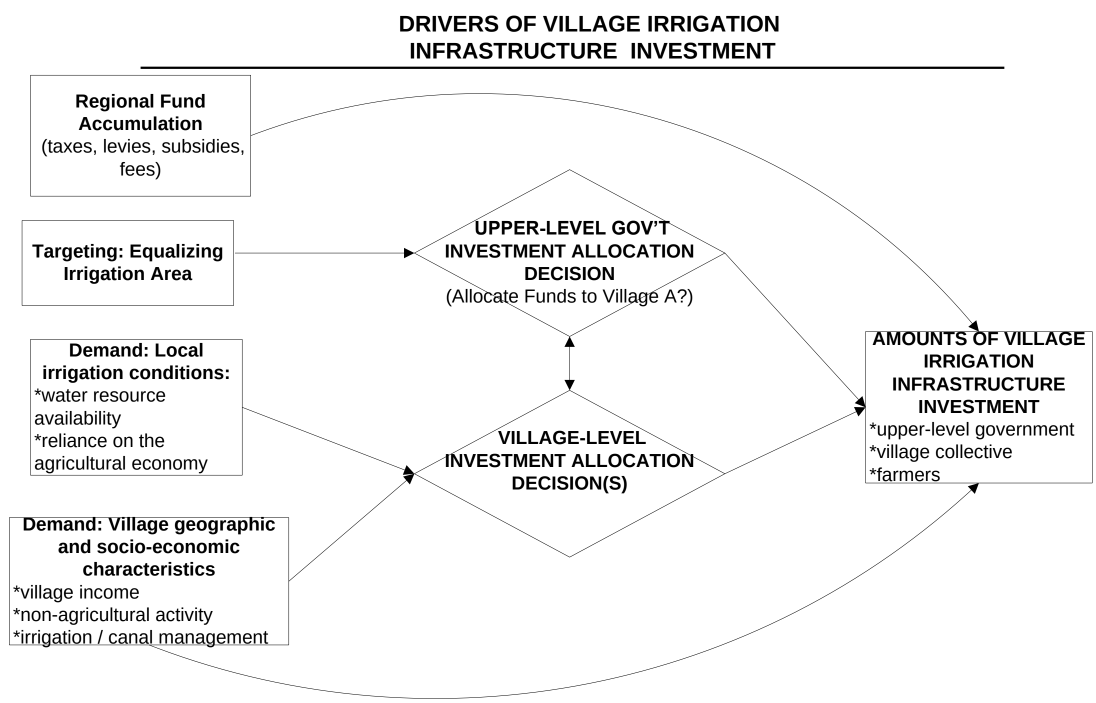


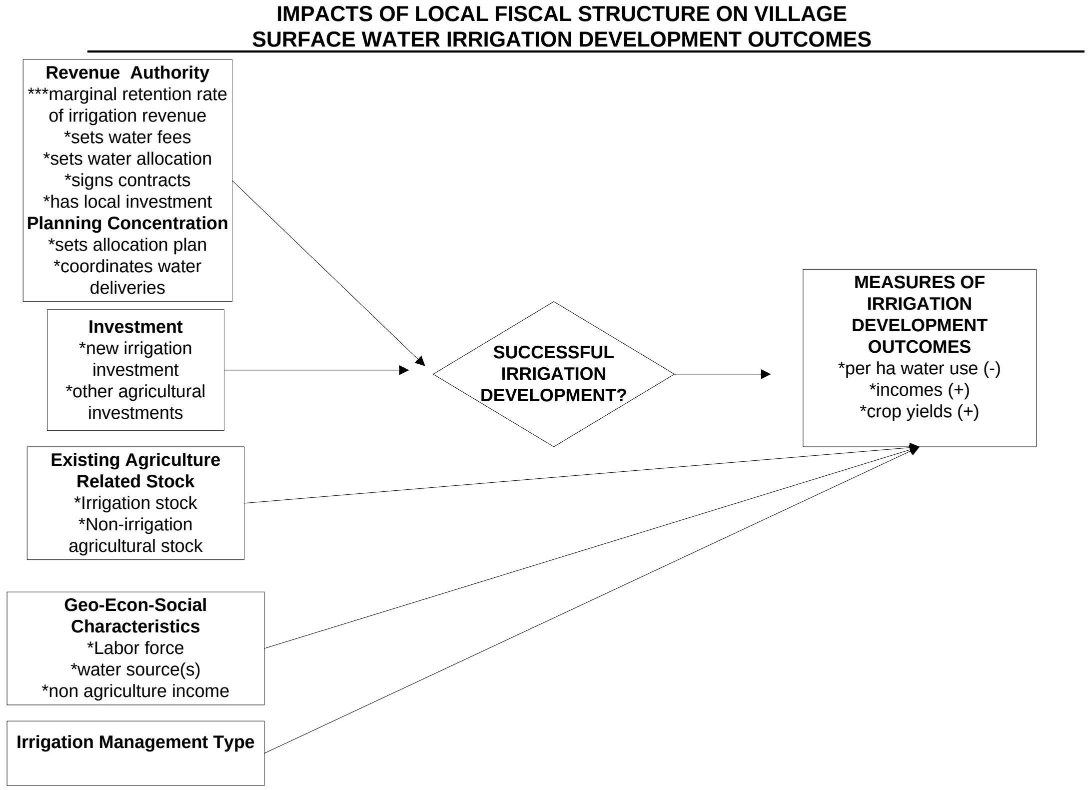
Figure 2 presents the conceptual framework to guide this portion of the study, referred to as 'drivers of investment'. It consists of two conceptual dimensions hypothesized to drive investment into village-level irrigation investment, targeting factors and demand side factors. The conceptual model illustrates the posed relationships among a village's irrigation investment composition, its irrigated area and local water resource conditions. For the upper-level government funds, investment levels are determined by: <u>targeting factors</u> including increasing effective irrigated area in China's villages and providing drought relief. For local funding sources, village collectives and farmers, the drivers to invest can be categorized as <u>demand drivers</u>, and drivers include a diversified village economy which generates funds for public goods including irrigation and securing water supply in villages with low water reliability in order to minimize uncertainty around crop watering. Other village-level variables are included as controls: whether or not the surface water manager is a cadre was found to influence the political capital in a village and the selection of villages for funding projects (Dong 2000); non-collective management such as water user associations or contractors divert budgetary decisions away from the village collective, thus impacting the flows of funds into irrigation infrastructure; Also considered are socio-economic factors such as number of agricultural workers and average farmer income in the village. The specific hypotheses associated with each of these control variables are too many to elaborate upon here, but significant effects will be discussed in the results sections in chapter 4.

2.2.2.2. Impacts of local revenue authority on irrigation development outcomes

Figure 3 depicts the posed relationships between a village's level of fiscal and water planning authority and three measures of village-level irrigation performance: crop water use, farmer incomes and grain yields. The literatures informing this conceptual framework are the fiscal decentralization and environmental governance bodies of work. Detailed review of the relevant literature, on which this conceptual framework is based, can be found in chapter 5.

Based upon the conceptual model illustrated below, villages with higher levels of authority (fiscal and water planning) retained by the village allow for provision of irrigation services closely tailored to local conditions, and therefore will result in better irrigation development outcomes. Fiscal authority is conceptualized in two ways. First, fiscal authority is represented as a village's marginal retention of irrigation revenue (MRR), defined as the portion of irrigation fee revenue retained by village for discretionary use as a share of total irrigation fee receipts. This conceptualization of fiscal decentralization has been used in several studies at the province, state or county levels (Oksenberg and Tong 1991; Lin and Liu 2000; Akai and Sakata 2002). Fiscal authority is also conceptualized by a number of other indicators regarding who has authority over village fiscal decisions including: who sets the irrigation fees, who decides on water allocation to farms, who signs contracts and whether or not a village has any local investment. The presence of local investment indicates discretionary spending authority is held at the village level.

Figure 3 Conceptual model for estimating impact of local fiscal structure on irrigation development outcomes



The concept of local water planning authority is also hypothesized as positively impacting local irrigation development outcomes. This hypothesis emerges from the environmental governance theory that localized decision making is based on local knowledge and integrates long-term resource use considerations into decisions, therefore local decision making will have more sustainable outcomes than bureaucratic decision making (Ostrom 1991; Agrawal 2002).

Other factors influencing irrigation development outcomes are investment levels, irrigation management institutions, land and water endowments and social economic factors such as village enterprise income and number of farm laborers in the village. Contracting has been found to result in lower crop water use levels as contractors receive payments to use less water (Wang, Xu et al. 2005). Contracting also indicates clearer ownership and division of responsibility over the canal network. More defined ownership structures are theorized to increased maintenance and investment into canal networks (Nobe and Sampath 1986; Ostrom 1992). Land and water endowments likewise affect water use and agricultural yields, in the positive direction, with villages with higher natural endowments using more water and producing higher crop yields (Fan and Zhang 2002). Additional discussion of hypotheses of variables with significant effects can be found in the Chapter 5 results section.

2.2.3. Summary

For both the drivers of investment and impacts of local fiscal and planning authority analyses, the study period covers 10 years, as recorded in 3 points in time. Several iterations of investment, fiscal and water resource policies changes occurred during the study period (see section 3.2, Timeline of economic and political events affecting irrigation development in China). Given the incremental adoption of policies across northern China, this study does not account for specific policy changes in the analysis. Instead, the analysis draws on the conceptual categories to measure on-the-ground changes in investment, fiscal structure and water planning authority that are likely driven by the multiple policy mandates.

2.3. Study Area: Northern China

The three provinces included in the survey study area (Ningxia, Hebei, and Henan) are in the north-central and north-eastern regions of China and located in the Yellow and Hai River Basins. Most of the study area is in arid and semi-arid zones.

Average precipitation in the upper reach of the Yellow River (Ningxia) is 523 mm, 671 mm in the lower reaches (Henan and Hebei). Rainfall in the Yellow –Hai river basins varies greatly both from year to year and within years. Thus, the Yellow and Hai river basins face severe flood and drought problems. Primary crops in all three provinces are first wheat, then corn. Rainfall throughout northern China is often insufficient to meet the water demand of wheat and corn crops throughout the entire growing period, making irrigation necessary to guarantee high agricultural yields.

Digging deeper into the issues of water scarcity, food production, and infrastructure provision decision making, this study expands understanding of land-society-natural resource interactions, in China and in arid regions of the world, by untangling the relationship between infrastructure investment, water resource scarcity and decentralized fiscal authority.

2.4. Data

At the core of this dissertation is a unique data set, the *2001-2008 Northern China Irrigation Management Survey*, designed and collected by researchers and staff at Center for Chinese Agricultural Policy (CCAP), a research institute of the Chinese Academy of Science. The main designers of the survey and sampling procedure were Dr. Jinxia Wang (CCAP), Dr. Scott Rozelle (Stanford) and Dr. Qiuqiong Huang (University of Minnesota). The field work team was made up of CCAP research fellows and graduate students from local agricultural universities. The author accompanied the field work team on a separate survey trip in 2006, and joined the Ningxia field work team in the 2008 data collection round. Data collection took place in the summers of 2001, 2004, and 2008.

The basis for this inquiry into the investment and infrastructure aspect of the larger research project is based upon a series of field work trips in Summer 2006 and Spring 2008 where the author observed stark contrasts in villages' irrigation infrastructure and agricultural conditions. While attending surveys in dozens of villages, the author observed one village with pristine water flowing through cement-lined canals and well-tilled farm plots, while in a village not five kilometers away, debris filled dirt ditches were devoid of water and looked unable adequately to deliver any water to the fields. Given these observations, the author decided to look closely at data on investment, agricultural water use and local political economies. Within the same county, villages had widely varying levels of irrigation investment, water use patterns, incomes and crop productivity. This work intends to explore this variation and explain how village-level irrigation-related fiscal structures, water resource conditions, and upper-level investment targeting, contribute to varying rural livelihoods and sustainable water resource use outcomes.

2.4.1. Study Population

The study population is villages in northern China, numbering around 20,000. Northern China is an area with acute water scarcity that includes 40 percent of the nation's cultivated area and houses almost half of the population (Lohmar, et al., 2003, Yang and Zehnder, 2001, Yang, et al., 2003).

2.4.2. Research design

This study uses panel data over a ten-year time period to examine hypotheses related to the impact of decentralization on investment disparities and irrigation development outcomes. Observed variation in the data is used to create observational groupings and analyze village characteristics at three points in time, 2001, 2004, and 2008. Time periods are used to define the length of time in which capital expenditures on fixed assets related to surface water infrastructure are made for periods: 1998-2001, 2002-2004, and 2005-2007.

This study takes place in a natural social setting, that is, the conditions explored are not designated or assigned by the research team. A survey was designed with the purpose to gather information in order to generalize from the sample of villages to the rural northern China population of villages, so that inferences could be made at the village-level.

Within the research population, two conditions were observed which indicated that experimentation in order to explain observed phenomena would be possible. First, variation in several outcomes of interest was observed (investment levels, water use behavior, agricultural productivity levels, and income) as well as possible explanatory factors (irrigation governance, village economic diversity, local fiscal policy and water resource supply options). Second, changes over time in many of these factors were observed, both the outcomes and the hypothesized explanatory factors. Given these conditions, the survey design team, and later the author in analyzing the secondary data, identified a quasi-experimental design as the most appropriate method to make inferences about the population.

Although the quasi-experimental design framework lacks the random assignment framework to support valid causal inferences that would occur in the absence of the experimental treatment (Shadish, Cook et al. 2002), careful design and control in logic, design, and measurement can help rule out alternative explanations for outcomes, and build a solid case for hypothesized explanations of observed outcomes. Unlike the clear control and treatment groups of an experimental design, in this quasi-experimental study comparison groups are formed, based on the main explanatory variables, to assess impacts of these variables on village outcomes over time.

Construction of comparison groups is not based on random assignment during the sampling process, but on assignment from analysis of the survey data. An advantage of this research design, as opposed to random assignment is that the study contains potentially fewer internal validity threats from omitted confounders than is the case for standard observational studies. In other words, the source of variation in treatment assignment is plausibly "exogenous".

The unit of analysis is the village. The village is selected as the unit of analysis because the village is the basic building block for rural China's bureaucracy and where large variation in irrigation investment sources, infrastructure, water supply, and investment levels are observed. For this reason, it is appropriate to analyze the village, its agricultural characteristics, its fiscal policy and irrigation-related investment as independent units.

2.4.3. Study sample

In total, the sample includes three provinces, fourteen counties, and seventy-eight villages. Due to the intensity of groundwater use for irrigation in many villages, the sample for this analysis is limited to villages using surface water or conjunctive use of groundwater and surface water (n=70). For the impacts of fiscal and planning authority analysis (chapter 5), the sample is limited to only Henan and Ningxia

Provinces (n=55) due to observed variation in the treatment variables in these provinces, and not in Hebei. The sample is too small to represent northern China, thus limiting the study's generalizability.

The data collectors describe the sampling procedure:

"To increase the variation among regions, provinces were chosen that were located in the upper (Ningxia) and lower reaches (Henan) of the Yellow River Basin, and the lower reach (Hebei) of the Hai River Basin. In selecting the irrigation districts for our study, a number of criteria were considered. From a number of IDs (irrigation districts) in each province, the two IDs were chosen based primarily on water availability, doing so by selecting one that is upstream in the province and one that is downstream. After the IDs were selected, we randomly chose sample villages from the census of villages in the upper, middle and lower reaches of the canals within the IDs" (Wang, Xu et al. 2006).

2.4.4. Survey instruments

Data from this large-scale project was elicited via three separate survey instruments. A subset of the data is selected from panel data variables in the *Surface Water Survey* and the *Village Irrigation Survey*. Surveys were written and conducted in Mandarin Chinese and translated by the author and staff at CCAP. The two survey instruments together form the *Northern China Irrigation Management* dataset which includes over 500 variables related to village-level irrigation governance in northern China. The dataset includes panel data for 78 villages in six irrigation districts, in three provinces across northern China (Hebei, Henan, and Ningxia).

Enumerators for the *Surface Water Irrigation Survey* interviewed each village's surface water manager. In some cases this person is also the village leader, in other cases, not. This survey is broken into ten sections covering topics related to irrigation system structure for surface water; water pricing, and detailed longitudinal surface water irrigation infrastructure investment. The investment worksheet section of the *Surface Water Irrigation Survey* asks the irrigation manager to report detailed records of village-level investments in surface water infrastructure between 1981 and 2008, per year, for investment in five physical infrastructure components: electrical facilities, canal lining, facilities and construction, pump and motor, and canal digging. Surface water managers consulted historic records to report how much was invested per item, per year for a thirty-year period.

In addition to the irrigation water manager, enumerators also interviewed the village leader in a separate *Village Irrigation Survey*. Village leaders in China have traditionally had irrigation management as one of their three primary duties (the others include tax collection and population control), and therefore the village leader is an appropriate person to provide irrigation-related information. The contents of the *Village Irrigation Survey* include a range of village characteristics elicited for three separate time periods, 1998-2001, 2002 – 2004, and 2005-2007. The survey instrument is divided into 13 sections and covers topics including the basic socio-economic situation of village, crop production, water resources utilization, water projects, water use, investment, and management.

In China, nearly all villages have accountants that maintain written records about many aspects of village life, including information on demographics, the economic structure of the village, income, land, etc. In addition (and importantly), most villages in the sample kept detailed, community-level records about village water issues. Enumerators also held detailed interviews with multiple stakeholders in the village—leaders, canal managers, and farmers—who had been village residents for the entire sample period (during 1981–2008). Given the importance of water, villagers had little trouble remembering their ‘‘irrigation histories.’’ In other words, the team is able to rely on leader/managers/farmer recall and accountant records to enumerate details of irrigation infrastructure investment.

All currency figures are in Chinese Yuan (also called RMB), and normalized to year 2000 Chinese Yuan using the China Statistical Bureau Rural Consumer Price Index.

2.5. Chapter Summary

This chapter presented two conceptual frameworks to provide the backbones of the overarching hypothesis of this study, that fiscal decentralization impacts irrigation development in a number of different ways. Two conceptualizations of processes of fiscal decentralization are presented: First, diversity in local irrigation investment sources and second, localized authority over revenue and water planning authority. In the drivers of investment conceptual framework targeting and demand side drivers of diverse irrigation investment are presented. In the impacts of local authority conceptual framework, two dimensions of revenue authority are hypothesized as impacting irrigation development outcomes. Although the full literature reviews are located in later analytical chapters 4 and 5, the basic conceptual formulations showing the relationship between fiscal decentralization and irrigation development are presented. The chapter next describes the northern China study area. Lastly, the *NCIM dataset*, population and sampling framework are described. The literature reviews, research questions, hypotheses and measurements through which these relationships will be assessed are included in the relevant analytical chapters, chapter 4 for drivers of village level irrigation investment and chapter 5 for the impact of local authority on irrigation development.

Chapter 3: Tracking modern the political and economic history of irrigation development in China

3.1. Introduction

Since the founding of modern China, several major shifts in policy aims for irrigation development have occurred, as have shifts in the economic and fiscal structure for making irrigation related investments. Shifts in policy aims for irrigation development include: a shift in the primary aim for irrigation projects from increasing the effective irrigation area, to rehabilitating existing irrigated area; shifts in water engineering aims from securing supply to water conservation, and renewed attention to increasing rural livelihoods while increasing irrigation efficiency. Alongside irrigation investment policy shifts, have been changes in China's fiscal structure from centralized investment planning to decentralized investment planning. However, within the decentralized system exists a wide range of levels of local authority over investment and water resource planning across China's villages.

Given the number of policy shifts impacting irrigation development, the purpose of this chapter is to understand shifts in fiscal policy and irrigation development leading up to, and during, the study period. To accomplish this, this chapter first lays out a timeline of major economic and political events affecting irrigation development in China. China's modern day irrigation development is divided into four stages for and chronicles investment trends and major policy changes occurring during each time period. Next, the chapter uses the *NCIM survey data* to empirically assess shifts in surface water irrigation development in northern China during the study period. Changes in composition of village-level irrigation investment portfolios, decision-making patterns for surface water irrigation infrastructure and irrigation system outcomes will be assessed based on the 70-village sample.

Tracking northern China's irrigation development serves two main purposes. First, providing basic facts and information describing northern China's irrigation situation provides an empirical analysis for scholars and policy makers alike struggling to improve the effectiveness of limited public funds to reach specific policy goals. Few studies have done this. Later multivariate analysis will further examine such variation. Second, turning a study of irrigation investment on its head, and examining decentralization from the village level upwards, provides a unique view of investment portfolios and related decision making. This bottom up view point contributes to a body of empirical evidence of how rural China fits into larger debates on central versus local decision making around investment making for local infrastructure projects. The question that remains in open debate is: at which jurisdictional level are water infrastructure projects best funded and planned?

A definitional note, the term *post reform* is debated in various academic disciplines. For the purposes of this study, *post reform* is defined following the tradition of political science scholars of China's institutions (Lieberthal and Lampton

1992; Oi 1999) as the period beginning in the early 1980s when rural China underwent two major institutional changes, de-collectivization of rural land and fiscal decentralization. These two institutional changes are the basis of the post-reform period, as defined for this dissertation.

3.2. Timeline of modern China's surface water irrigation investment and development

The following timeline divides irrigation development in modern China into four phases of development, with greater attention to phases following the 1979 opening up and economic reforms.

3.2.1. Phase I (Pre-1979): High subsidy – rapid irrigation development era

After the founding of the People's Republic of China in 1949, Mao Zedong and the Chinese Communist Party focused national policy toward to the restoration and construction of irrigation conservancy projects. Irrigation development projects were heralded as an important part of national economic recovery following years of civil war. During the "Great Leap Forward" and "people's commune movement" in the 1950s and 1960s, although agricultural yields plummeted, China's effective irrigation area grew at average annual rate of 3.1% (MWR 1988). The national government in the 1950s and 1960s met its irrigation development goals of increasing water supply and expanding China's effective irrigated area.

During the Cultural Revolution era between 1965 and 1975, effective irrigation area expanded from 32.04 million hectares in 1965 to 46.12 million hectares in 1975, an average annual growth rate of 3.7% (MWR 1988). Investment into water infrastructure also rose particularly fast during this period, with an average annual growth rate of 10.1% (MWR 1988). However, 1975 marked the end of the China's high subsidy-rapid irrigation expansion phase. Beginning in the mid-1970s, irrigation investment patterns changed throughout China. By the late 1970s central government funds to expand irrigated areas ceased and funding to maintain irrigated areas also decreased (Lohmar, Wang et al. 2003).

3.2.2. Phase II (1980-1989): Economic opening up, irrigation investment declines

The year 1979 marked the beginning of Deng Xiaoping's opening up and economic reform period in China, and drastically altered China's economic and political landscape. Although the early 1980's rural reform and opening up policy greatly contributed to China's agricultural and rural development in the early years of the reforms (Brandt, Huang et al. 2002), at the same time irrigation construction entered a phase of unprecedented setback. Effective irrigation area fell from 48.66 million hectares in 1982 to 47.87 million hectares in 1986. In four years irrigated area declined by 79 million hectares, an average annual decline rate of 0.4%, making this the first time since 1949 that irrigated area declined (MWR 1988). Water infrastructure investments accounted for only 2.7% of infrastructure investment during this period. As investments into urbanization and industry became the national investment focus, irrigation development was neglected (MWR 1988)

Several policies in the early 1980s contributed to declines in irrigation development. First, the 1980 fiscal reform called 'eating in separate kitchens' made each sub-national unit of government responsible for its own revenue and expenditures. A “bottom-up revenue structure” (Oi 1992) which was instituted in the late 1980s and has been referred to as “federalism, Chinese style” (Tsui and Wang 2004) mandated higher rates of locally retained and controlled revenue. Under such revenue sharing agreements, in effect through 1993, local governments gained greater discretion and flexibility in deciding how to generate revenue and make expenditures (Oi 1992).

The revenue sharing policies negatively impacted irrigation development in a number of ways. A study examining the revenue sharing policies in rural China finds that villages opted not to invest in agriculture-related projects as agriculture generates the lowest returns to local government. This is because agricultural tax doesn't go to the village, while tax receipts for village enterprises go directly to the village collective coffer (Oi 1992). Therefore, local government will prefer to invest in enterprises benefitting the local revenue base such as electricity and roads. Next, under the rural revenue-sharing fiscal structure, the central government ceased to provide large subsidies for local irrigation systems (Lohmar, Wang et al. 2003). Under this system village collectives experienced revenue shock as the central government no longer financed irrigation or water conservation projects, and villages lacked funds to maintain existing irrigation systems.

Another major policy shift was the *Household Responsibility System* (HRS), first adopted into China’s agricultural system in 1981. Questions of ownership over village assets under HRS contributed to declines in investment and upkeep of irrigation systems. Under the HRS, the village collective retained ownership of village-held productive assets, including the irrigation system components (canals, pumps, and water). However, due to unclear designation of responsibilities following HRS, village leaders throughout China did not designate funds to build or rehabilitate agriculture related infrastructure (tube well maintenance, field terracing, canals and ditches). Where the village collective had been responsible for constructing small- and medium-scale projects, under HRS, they no longer performed this type of project finance and supervision role (Watson 1989; Dasgupta 1997) and hardly any new projects were built, nor were existing infrastructures well-maintained. Village collective leaders did retain irrigation management responsibilities including within-village fee collection and allocation decisions. Finally, contrary to expectations of Chinese and foreign economists, post-HRS, farmers did not make private farm-level investments despite potential to improve agricultural productive capacity (Dong 1996; Dasgupta 1997).

The HRS rural reforms affected China's local irrigation systems in several ways. First, a lack of clarity in village ownership structures under HRS, left the ownership and responsibility over shared assets such as irrigation canals in question, and the systems fell into neglect (Wang 2007). Canal linings fell apart, sluice gates ceased to work and trash and debris filled canals throughout China's rural landscape. By the mid-1980s, fiscal policies mandating local self-reliance left many villages unable to maintain or rehabilitate much of the canal infrastructure built during the mid-20th-century (Lohmar, Wang et al. 2003).

Finally, implementation of the *Law of Ratification, Collection and Management of Irrigation Water Fees* in 1985 put an end to the free water supplies for irrigation and somewhat improved the sustainable financial operation of irrigations projects. The administratively determined fees however, remained well below the cost of the water (raw supply, operations and maintenance), often lined the pockets of local officials and bureaucracy and did not promote investment into water-saving irrigation systems.

Such declines did not go unnoticed by China's central government. In 1986 and 1987 the Rural Policy Research Office of Chinese Communist Party Central Committee Secretariat and the Ministry of Water Resources held successive Rural Water Forums in which they identified the existing crisis in China's irrigation sector including:

- A large number of irrigation project were aging and needed repairs;
- The drainage capacity of river discharge significantly decreased,

mainly due to aging wells, other irrigation equipment reaching obsolescence, dilapidated facilities, engineering failures and industrial buildings using irrigation water.

- Serious water shortages occurring in North China and coastal areas.
- Water pollution reached alarming proportions (1987)

3.2.3. Phase III (1990-1997): Local irrigation investment declines

Ministry of Water Resources investment data indicates that policies resulted in declines in on-the-ground investments into irrigation. In fact, water infrastructure investment as a share of total government infrastructure spending declined during the first 15 years of the reform period from 7.1% in 1978 to 1.7% in 1996 (MWR 2000-2008).

As the economic reform period progressed, the government modified the ways in which localities and the central government split revenue and spending responsibilities. In 1994 the Chinese government launched reforms to re-structure central-provincial fiscal relationships, aiming to replace the previous revenue-sharing system with a tax-sharing system (*fenshuizhi*) between provinces and the central government, and also used the system to structure province and sub-province jurisdictions (counties, municipalities, townships, villages) (Zhang 1999). As part of the 1994 reforms, irrigation investment decision making devolved to local administrative units (counties, townships, irrigation districts, villages) to raise funds and administer irrigation investment projects (Lohmar 2002).

These changes in China's fiscal system impacted irrigation development in a number of ways. Foremost, local governments assumed greater responsibility for funding local irrigation projects through locally generated revenue. Despite responsibility for funding local irrigation projects transferring from central to local governments under the 1994 fiscal reforms, the central government continued to issue mandates for reforms aimed at increasing water-use efficiency (Huang, Rozelle et al. 2009), increasing grain production (Yang and Zehnder 2001) and alleviating poverty (Huang, Dawe et al. 2005), thus creating a dynamic push and pull relationship between the village's fiscal authority and the policy mandates of the overlying bureaucracy. The 1990s drive toward industrialization resulted in general neglect of irrigation maintenance and development.

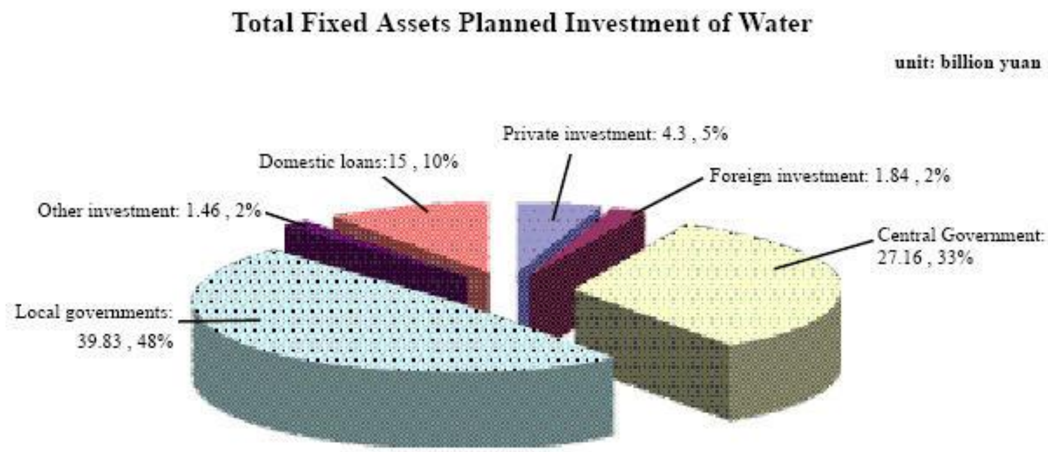
3.2.4. Phase IV: (1998-2007) Renewed attention to water conservancy leads to increased, yet uneven investment

The observed under-provision of local irrigation development by fiscally independent village collectives in the 1980s-1990s (Lohmar, Wang et al. 2003) combined with regional water shortages during the same period, help explain why China's central government stepped in to provide funds for village-level irrigation development during the late 1990s (Hiroshi 2008). The government took notice that the inability or unwillingness of villages to build or maintain irrigation networks was disrupting agricultural livelihoods, wasting scarce water resources and thereby threatening national food security. China's leaders noted concern that declining irrigated area and water shortages threatened northern China's wheat crop (Development 2004), and responded with a series of policy directives to increase spending on agricultural water projects.

Following the international trend in the 1990s toward institutional reform in water resources management, led by major development agencies, China also began widespread management reforms including pilot projects with water user associations (WUAs) in the late 1990s. These reforms aimed to increase coordination over water management and conserve water (Huang, Rozelle et al. 2009). Local water management reform is supposed to rely on increased participation by farmers and better incentives for managers to improve access to water and increase the efficiency of the system (Wang, Xu et al. 2006). Recent findings indicate that local institutional reforms in China have failed to achieve desired results in water conservation due to problems of collective action and a lack of proper incentive structures to promote more water use efficiency (Wang 2005).

Owing to the shift in policy concerns back to rural and agricultural development, investment into irrigation during Phase IV increased and investment sources into water conservancy development diversified to include higher amounts from central government agencies. By 2005, 48% of funds for water infrastructure were invested by local level governments (See Figure 4) including provincial, municipal, and village-level governments, and thirty-three percent of investment funds came from China's central government. The central government during this phase began to re-open funding channels into irrigation development.

Figure 4 Investment sources for water infrastructure in China, 2005



Source: "2005 Statistic Bulletin on China Water Activities" Ministry of Water Resources: Beijing, China

To address mounting concerns over rural social stability, in 2002 a policy called tax-for-fee reform (*fei gai shui*) was introduced to relieve financial pressure on villagers who were being levied fees from local governments looking to generate revenue. The tax-for fee reform eliminated fees levied on rural households, and replaced the fees with a single agricultural tax. Recent examination of the policy suggests that while the reform may relieve peasant fee burdens significantly, the initial impact on water resources and agricultural production indicates problematic trends in water use and crop yields (Mushtaq, Khan et al. 2008). The tax-for-fee reform re-routed "fee" revenue away from the village-collective, thus revoking villages' discretionary spending funds, some of which had previously supported public irrigation projects.

Such policies aim to improve rural conditions induced by highly decentralized policies of the 1990s where villages became financially self-reliant and responsible for both revenue generation and provision of local public goods and services. The end result being high levels of inequality, between regions and villages, and crumbling rural public goods brought about by the villages' struggle to generate revenue sufficient to provide such high cost goods and services. Additional rural reforms aimed at easing the burden on farmers included abolition of the agricultural tax in 2006 (Yu and Jensen 2010) which further limited local revenue to support public works projects.

The ending of fees and taxes was accompanied by direct investment and project oversight by local irrigation districts (IDs) into village irrigation projects. After the cessation of the village levy, village expenditure for public services was to be financed by budget transfer from upper-level administration and by case-by-case basis fund collection (*yishi yiyi chouzi*) (Hiroshi 2009). This reform re-shifted the levers of control in local irrigation investment planning and decision making, moving authority from the villages, and up to regional water authorities.

3.2.5. Summary

The push – pull dynamic between funding originating at the local level, but with strong policy mandates from the upper-level government has created an interesting paradox in China's local-level irrigation planning and development. On one hand, the national government re-prioritized policy initiatives to improve irrigation systems by directing millions of Yuan in investment funds to local governments for rehabilitating irrigation systems and promoting water conservation (Wang, Ren et al. 2000). However, despite billions of Yuan in expenditures being pumped into water-saving technologies and irrigation management reform initiatives, studies indicate that adoption of water-saving technology in villages and on farms is low (Blanke, Rozelle et al. 2007). On the other hand, farmers and village collectives are responding to water shortages and land use change, but not necessarily by conserving water. Farmers' primary response to water shortages has been to modify crop selection (Wu, Liu et al. 2005), sink tubewells (Wang, Huang et al. 2005) and develop private groundwater markets (Zhang, Wang et al. 2008), while continuing to utilize surface water sources as available. Although northern China's water shortages are acute, farmers continue to utilize consistent rates of water per hectare, aside from cases when water managers receive incentives to reduce water use (Wang, Xu et al. 2006). Upper-level government efforts and local efforts, at times appear to contradict each other's water use goals.

Based evaluation of the four irrigation development phases, one can see that owing to large investments pre-economic reform, China has a large intended irrigation service area. However, many years of neglect and lack of maintenance for these structures had greatly decreased the efficiency of these systems. The resurgence of investment since 1998 shows promise of improving the irrigation efficiency of China irrigation systems, but the complex jurisdictional issues brought about by several waves of fiscal policy reform present challenges to village-level irrigation development.

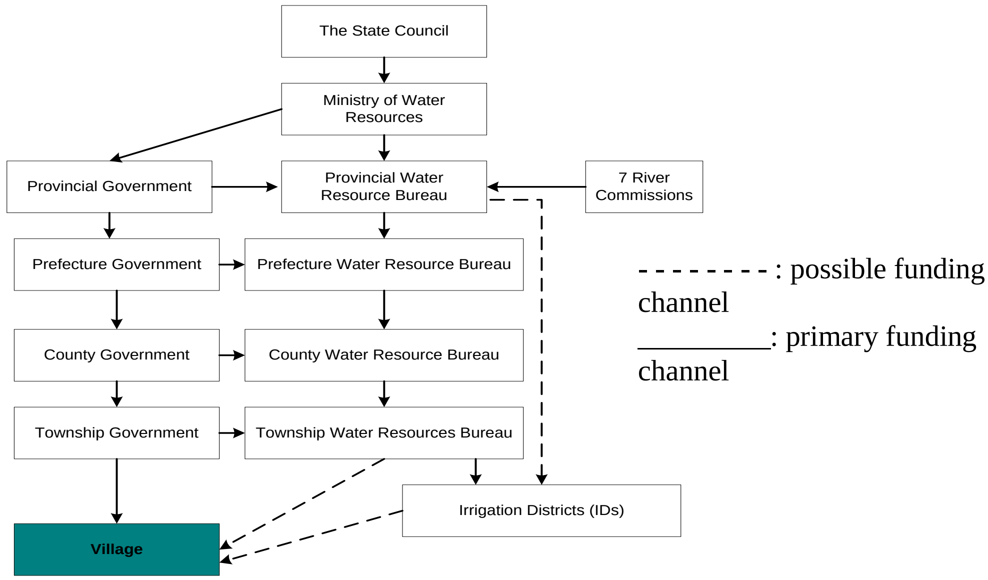
3.3. China's multi-layered irrigation development system

Understanding how fiscal structure impacts irrigation development necessitates understanding both the larger bureaucracy for irrigation-related funding and village-level financial structures for irrigation projects. This section describes each of these structures.

There is no single agency or ministry that has an overall mandate for irrigation development in China. Overlapping of irrigation – related activities exist in institutions at national, provincial, county and village levels. Within the village setting multiple policy efforts often take place, most often introduced and implemented by the village leader and party secretary (Tsui and Wang 2004). But in fact, each policy effort is also organizationally embodied in a particular ministry or set of bureaus within a ministry. Agricultural concerns are the responsibility of the Ministry of Agriculture, Forestry, and Animal Husbandry, water resource policy is controlled by bureaus within the Ministry of Water Resources, however, large capital projects related to irrigation infrastructure construction are carried out by the Ministry of Construction which is responsible for management of township infrastructures, and water supply projects. Also at play are the territorial interests of various counties, townships and villages due to position along the irrigation system scheme (upstream, downstream etc.), or local interests related to flood protection, hydro-power development, agricultural development, or water –starved industry (Lampton 2009).

Despite the fragmentation, the administrative set up for irrigation funding through a particular government agency is relatively straightforward. Administrative units, falling below nation and province, follow a hierarchal order of prefectures, counties, townships, towns, and villages (Wong 1997). The Ministry of Water Resources bureaucracy, which overseas irrigation water distribution and infrastructure development, follows a similar hierarchical structure corresponding to the governmental levels (see Figure 5), with the addition of a sub-county unit of irrigation districts. Irrigation district functions include supervision of intra-village water allocation and distribution.

Figure 5 Vertical and horizontal structure of the Ministry of Water Resources

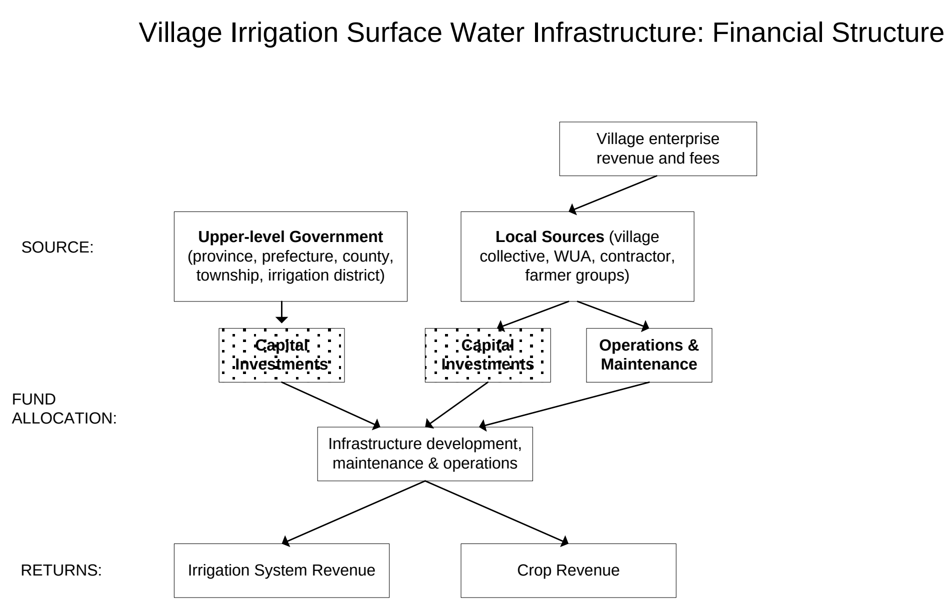


Each village relies on a variety of funding processes and sources for irrigation development projects. One source is township- and county- investment funds for re-distribution to village-level irrigation development. These upper-level government funds originate in two main ways. First, from the central government budget for village irrigation development, funds flow through the bureaucracy and typically end up expended via specific projects and larger –scale projects (for example regional seepage control or irrigated area expansion) carried out in villages.[4] Most large-scale infrastructure projects include seed funds from the central government and are matched by investment from a local administrative unit. This cycle of matching is replicated throughout China's infrastructure and development economy, with an upper-level source initiating the project, and a local jurisdiction providing project

[4] Examples include project to conserve agricultural water; projects to intensify irrigated area; and projects related to flood control (see World Bank reports on irrigated Agriculture Intensification Loans).

support and matching funds (West 1997). Aside from upper-level funding, a second investment source for village-level irrigation development is intra-village sources including farmers, village collectives, contractors and WUAs. A basic schematic of the financial structure of village-level irrigation infrastructure development is laid out in Figure 6.

Figure 6 Basic financial structure of village irrigation development



3.4. Tracking surface water irrigation investment in northern China

This section uses the *NCIM survey data* to lay out a narrative and empirical picture of the diversity in irrigation investment profiles and fiscal decision making in villages within the study area between 1998 and 2008. Diverse irrigation portfolios are one measure of indication of a decentralized fiscal landscape, with multiple funding sources contributing to a village's investment portfolio. This first sub-section aims to describe the distribution of investment within and between villages to understand the channels of decentralized irrigation investment. The second section describes villages' fiscal structures and processes and examines the relationships between various forms of fiscal decision making authority and irrigation development outcomes. Varying levels of revenue and spending authority are a second indication of shifting center-local fiscal relationships. The overall aim of tracking irrigation investment and investment decision making is to account for the shifts in levels and patterns of irrigation investment and related irrigation outcomes so subsequent chapters can further explore what drives these changes.

Because two different survey instruments are used to complied the data (the *Surface Water Manager Survey* and the *Village Leader Survey*), the time periods accounting for different investment types do not match throughout the assessment. All attempt to make the time periods uniform have been made.

3.4.1. Northern China's diverse irrigation investment portfolios

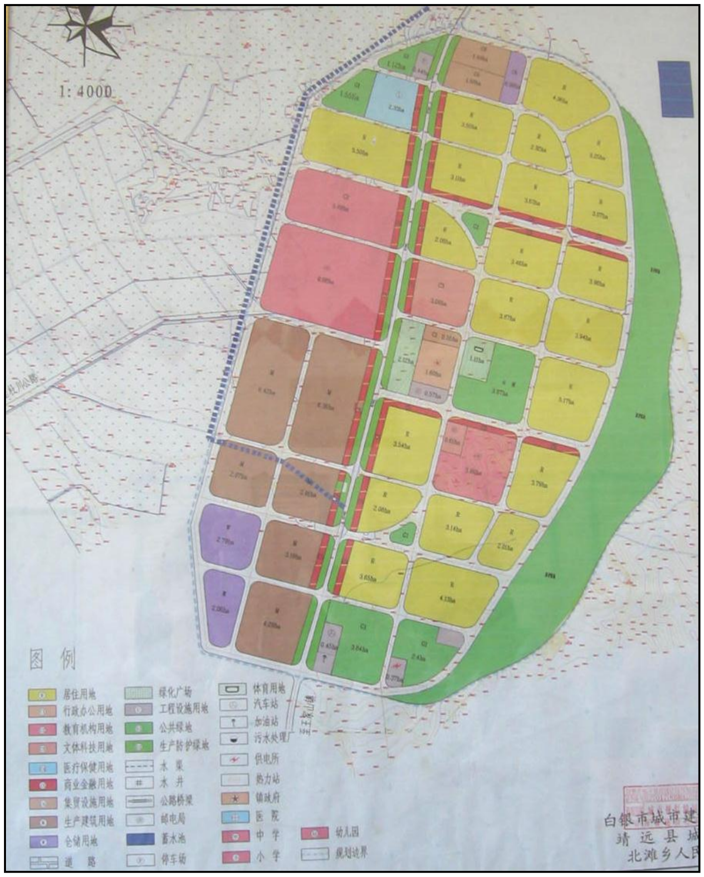
This section uses panel data set from northern China to track and describe northern China's irrigation landscape based on village leader and surface water manager reports of their irrigation systems between 1998 and 2008. In addition to describing the infrastructure, this section also includes reports of villages' investment sources and projects, as well as financial decision making within the village irrigation system.

3.4.1.1. <u>Village-level surface water irrigation investment portfolios, 1980s – 2008</u>

<u>Surface water irrigation systems types and sizes</u>

Canal system size over the three provinces varies widely. Hebei's canal networks are relatively small, averaging 2,415 meters of lateral canal network per village. In comparison Ningxia's irrigation systems are large, averaging 11,000 meters of lateral canal per village before expansion, and over twenty thousand meters per village following major canal expansion completed by 2001. The lateral (also called tertiary) canals feed off the branch canals and run throughout the village feeding farm-plots and field ditches. Figure 7 shows a typical village irrigation schematic, with the blue dotted line representing the branch canal, feeding the lateral (white line) canals throughout the village. Field ditches connect farm plots below the tertiary canal level. On average, 92 households per village irrigate with surface water in Hebei villages (see Table 1), 281 households per village irrigate with surface water in Henan and 341 households per village in Ningxia. These numbers can be used to calculate the spatial density of the network. Villages in Ningxia average 44 meters of lateral canal length per household, indicating either very large farm plot size, or spatially dispersed farm plots. In contrast, canal density in Henan averages seventeen meters per household, a more compact canal-to-farm spatial structure.

Figure 7 Map of village's spatial organization in northern China



Author's photo, July 2006

Table 1 Village –level canal system characteristics

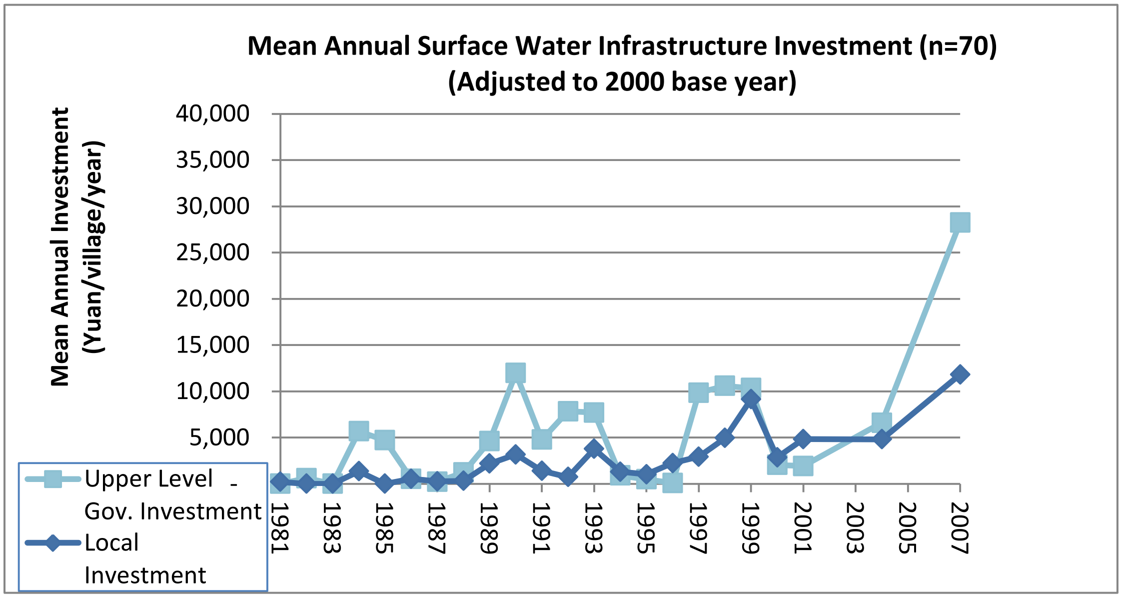
	Hebei	Henan	Ningxia
Average length branch canal (m):	1,761 (1,892)	1,161 (1,836)	5,618 (5,176)
Average length lateral canal (m):	2,415 (1,693)	4,790 (3,371)	15,018 (18,298)
Surface water irrigating households (hh/village):	92	281	341
Density Measure (meters *branch canal* per household):	19	41	165
Density Measure (meters *lateral canal* per household):	271	17	44

Data source: Center for Chinese Agricultural Policy, Chinese Academy of Sciences
*system size was generally stable between 1981 and 2001, with the exception of canal length expansion in Ningxia
n=210, standard deviation in parentheses

Most villages in northern China use a combination of gravity and pump-powered irrigation to water crops. In Hebei, the primary crops are wheat and corn, for which gravity irrigation is used for 50% of surface water applications, and pump-power for the other 50% of surface water applications. In the data, the time of application and the spatial location of application are not designated, only which crop and depth of irrigation water application are reported. In Henan, where rice paddies are cultivated in addition to wheat and corn, a similar split is seen between gravity and pump surface water applications. Farmers use gravity irrigation 52% of the time and pumps 48% of the time. Crop diversity is greater in Ningxia where farmers plant melons, vegetables, and fruit, in addition to wheat, corn and rice. Ningxia farmers overwhelmingly rely on gravity fed systems. Pumps are utilized for surface water irrigation for only 10% of field applications, with the other 90% of the applications being gravity fed.

One way that government and farmers have responded to economic and environmental perils in rural China is a renewed focus on modernizing the agricultural water sector. At the local level, despite the fact that low surface water prices leave little capital accumulation in village budgets to repair or invest into canal systems (Ou et al. 2002; Yang et al. 2002), villages continue to invest in irrigation infrastructure (see Figure 8& Table 2). Across the full sample, village collective investment declined to 18% in 2008 from 26.2% in 2004, primarily driven by a substantial drop in Hebei. In the 2002-2008 period, private investment became a larger share of village investment portfolios in Henan and Ningxia. This corresponds with the increased number of contractors and WUAs in these provinces who fall into the private investment category (Huang, Rozelle et al. 2009). These changes also correspond with the increase in direct irrigation project development of irrigation districts following the tax for fee reforms and agricultural tax abolition.

Figure 8 Village- level Surface Water Infrastructure Investment in Northern China



Data source: Center for Chinese Agricultural Policy, Chinese Academy of Sciences
Notes: Upper-level investors include: provinces, counties, and irrigation districts; Local investors include: village collective, water user associations, and farmers.

Table 2 Sources of funds for surface water irrigation projects (in 2000 Yuan)

	Quantity of investment (Yuan/village/year)[a]				Percentage of investment (%)		
	Village Collective	Private[b]	Government	Totals	Village Collective	Private[b]	Government
Total sample							
1981-1990	2,072	-	7,451	*9,523*	21.8	-	78.2
1991-2001	14,482	6,167	34,703	*55,352*	26.2	11.1	62.7
2002-2008	14,169	22,235	38,652	*75,056*	18.9	29.6	51.5
Hebei Province							
1981-1990	133	-	75	*208*	64.1	-	35.9
1991-2001	692	6	71	*769*	90.0	0.8	9.2
2002-2008	1,248	1,319	14,550	*17,117*	7.3	7.7	85.0
Henan Province							
1981-1990	378	-	1,310	*1,687*	22.38	-	77.62
1991-2001	6,611	3,628	5,162	*15,401*	42.92	23.56	33.52
2002-2008	3,755	880	2,228	*6,863*	54.71	12.83	32.47
Ningxia Province							
1981-1990	1,561	-	6,066	*7,627*	20.47	-	79.53
1991-2001	7,179	2,533	29,470	*39,182*	18.32	6.46	75.21
2002-2008	9,166	20,036	21,874	*51,076*	17.95	39.23	42.83

Data source: Northern China Irrigation Management Survey, Center for Chinese Agricultural Policy, Chinese Academy of Sciences
a. CPI adjusted with 2000 as the base year.
b. Private includes: farmers, small farmer groups, contractors, and WUAs.
notes: Quantities include cash investment only, and do not include labor inputs by villagers; Hebei has 14 sample villages, Henan has 24 and Ningxia has 32.

Although data indicate an overall rise in investment in northern China since 2000, the total amount expended on surface water irrigation in the seventy sample villages varies widely between provinces. Ningxia had the highest investment levels during the twelve years in which the survey requested project-specific infrastructure expenditure data, at an average of approximately 2.4 million Yuan per year (USD $362, 427), while Hebei spent the least, averaging 251,000 Yuan per year (USD $37,671) throughout the study period (see Table 3). Per village spending in Henan was the lowest in the sample averaging 23,000 Yuan per village per year, while in

Ningxia annual per village expenditures averaged 75,000 Yuan and 50,000 Yuan per village per year in Hebei.

Table 3 Investment quantity and classifications for surface water irrigation projects, 1996-2008

	water supply security projects[a]		performance improvement projects[b]		total expenditures (Yuan*)
	investment amount (Yuan*)	% of expenditures / source / project type	investment amount (Yuan*)	% of expenditures / source / project type	
full sample					
village collective	1,000,246	2.8%	8,496,637	24.1%	9,496,884
farmers	2,354,594	6.7%	1,487,659	4.2%	3,842,253
upper-level government	1,201,763	3.4%	20,737,049	58.8%	21,938,812
Hebei Province					
village collective	112,495	3.7%	249,650	8.3%	362,145
farmers	15,240	0.5%	204,614	6.8%	219,855
upper-level government	51,691	1.7%	2,381,542	79.0%	2,433,232
Henan Province					
village collective	115,015	3.5%	565,832	17.4%	680,847
farmers	1,374,031	42.2%	68,159	2.1%	1,442,191
upper-level government	117,676	3.6%	1,013,328	31.1%	1,131,004
Ningxia Province					
village collective	772,737	2.8%	7,681,155	27.5%	8,453,892
farmers	420,941	1.5%	658,109	2.4%	1,079,050
government	1,032,397	3.7%	17,342,179	62.1%	18,374,576

*Yuan is inflation adjusted to base year 2000
Data source: Northern China Irrigation Management Survey, Center for Chinese Agricultural Policy, Chinese Academy of Sciences

Irrigation infrastructure components: canal digging, pump, electricity and diesel generators, electricity line

Irrigation infrastructure components: underground pipes, surface pipeline, measuring equipment, sprinklers, drip facilities, buildings

Sources of funding

In order to understand the changes in irrigation investment over time and between different sources in villages, the rate of investment per village is calculated for three main investment sources, upper-level government, village collectives and private sources including farmers, small groups of farmers, contractors and WUAs. Investment rates and composition of investment vary between time periods and provinces (see Table 2). Hebei stands apart from the other two provinces for its low average investment into surface water irrigation works at 6,032 Yuan per year village, compared with Henan and Ningxia at 7,984 Yuan per year village and 32,628 Yuan per year village, respectively for annual average between years 1996 and 2008. Further, villages in Hebei rely almost entirely on within-village investment for surface water irrigation infrastructure, up to the 2002-2008 period where overall investment increased, and upper-level government investment as a portion of the total, comprised 85.0% of village surface water irrigation investment.

Where farmers comprised up to 23.6% of surface water irrigation infrastructure investment in Henan between 1991 and 2001, in Ningxia during the same period, upper-level government contributed 75.2% of the funds, which were also more than double the mean village rate of investment for Henan during the same time period, 15,401 Yuan per village for Henan, and 39,182 Yuan per village for Ningxia.

Spending on surface water irrigation infrastructure sky-rocketed in Hebei between 2002 and 2008 spurred by almost 2.4 million Yuan in infrastructure investments provided by the Hebei Province Water Resource Bureau, amounting to

40 Yuan per irrigated hectare in Hebei Province during this 6-year time period (17,117 Yuan per year per sample village). Per hectare spending may be a better indicator by which to compare spending to compare the capital expenditure rate instead of the absolute amount. Per hectare spending in Hebei was a low 3.58 Yuan per irrigated hectare between 2002 and 2004, while in Ningxia per hectare expenditures in the same time period were 15 Yuan, and 3.75 Yuan per hectare in Henan. The highest per hectare spending during the study period was in Ningxia between 2005 and 2008 with 40.34 RMB per hectare spent on surface water irrigation development.

Within the 70-village sample, investment into surface water infrastructure, both by upper-level government agencies and local investors, namely village collectives, contractors, WUAs and farmers, fluctuated during the study period, although annual mean per village investment increased after 1988 (see Figure 5). Throughout the 30-year period, mean upper-level investment is greater than mean local investment, with exceptions in years 1995 and 2001. In 1995 local mean local investment was 1,104 Yuan (USD 160) per village and mean upper-level investment per village was only 487 Yuan (USD 70.88) per village. Such numbers illustrate a pattern of very low quantity of investment over all. During the tail end of the study period there is a sharp spike in mean investment levels for all investment sources, with an average of 28,000 Yuan (USD 4,174) per village from upper-level government, and 12,000 Yuan (USD 1,789) per village from local sources.

Project types and infrastructure components

To understand more about the project types into which projects government, village collectives and farmers invest, this section examines investments according to project type, where projects are categorized according to the project aim of 1) securing water supplies or 2) improving irrigation performance.

The primary infrastructure investment project for irrigation is construction of buildings and canal lining with sand, stones, or cement (see Table 4), amounting to 82% of project funds between 1996 and 2001, and 61% and 69% of total project investment in 2002-2004 and 2005-2007, respectively. Both project types aim at improving irrigation performance and efficiency. Lining existing canal networks reduces seepage and increases delivery efficiency en route to the fields. Canal lining comprised 62% of village collective project funds in Henan and 30% of village collective funds in Ningxia.

Table 4 Surface water investment quantity, by project type

	(Yuan* / time period)						
	water supply security projects[a]			performance improvement projects[b]			
	canal digging	pumps & motors	electricity / diesel	canal lining	measuring equipment	buildings & facilities	**total expenditures**
Full sample							
1996-2001	608,893	1,552,510	138,991	8,568,714	-	12,619,120	**25,788,621**
2002-2004	454,371	197,245	-	1,896,363	33,025	232,115	**3,464,735**
2005-2007	730,820	430,791	442,983	5,188,794	21,336	2,161,879	**10,581,197**

* Yuan is inflation adjusted to base year 2000

a. Irrigation infrastructure components: tubewell, pump, electricity and diesel generators, electricity line

b Irrigation infrastructure components: underground pipes, surface pipeline, measuring equipment, sprinklers, drip facilities, buildings

Data source: Northern China Irrigation Management Survey, Center for Chinese Agricultural Policy, Chinese Academy of Sciences

Water supply security projects comprise much smaller share of villages' irrigation investment portfolios, but interestingly comprise a large share of farmers' investments, 42% (1,374,031 Yuan) of total investment in Henan and 6.7% of total investment share across the entire sample (see Table 3). Measuring equipment remained low on the project expenditure list for all investment sources across provinces. During the last survey round in 2008 however, farmers and villagers indicated increased funding toward water gates including sluice gates and on-field gates to better control water delivery. Other infrastructure expenditures include pumps, electricity facilities, and other maintenance and rehabilitation projects that are constructed to improve the performance of existing irrigation systems.

Data indicates a dramatic shift in investment activity by farmers. Private funds investment in Henan amounts to over 1.4 million Yuan over the twelve year period (see Table 3). The majority of funds invested by farmers and WUAs went toward pumps and diesel engines, indicating the need to move water over flat and uphill terrain to reach outlying fields. In Ningxia, expenditures by upper-level government and village collectives are roughly even, as are expenditures between similar project types. Government records and interviews indicate that upper-level agencies often provide funds conditional on matching funds provided by the local government, and expenditures into priority irrigation development projects (Interview with Water Resource Engineer in Ningxia, 2008). These investment records support such policy structures.

3.4.2. Relationship between drivers of investment and investment sources

This section explores the drivers of investment from three sources contributing to village-level irrigation investment portfolios – upper level government, village collectives and farmers.

3.4.2.1. <u>A progressive investment policy?</u>

A hypothesis examined in this dissertation (see section 4.3.2.) is that the upper-level government is pursuing a progressive investment policy by targeting villages with less capacity to service their intended irrigated area. According to the *NCIM data*, upper-level government investment is greater, on average, for villages with existing high irrigation service levels (see Table 5). During the later survey period, 2005 to 2007, investment levels of villages with high share of irrigated area were considerably higher than villages with lower capacity to irrigate their land. To evaluate whether or not China is engaging in a progressive irrigation investment strategy, such results suggest that more in-need villages are not receiving investment funds, but villages that already have relatively high-functioning irrigation systems continue to receive the bulk of investment funds. In the three investment periods analyzed, villages with above median levels of service provision consistently have higher levels of investment than villages with below median service provision levels (see Table 5).

Table 5 Village's irrigation service level* & investment funds received from upper-level government (n=70)

	Mean per period investment according to irrigation service level (normalized to 2000 RMB) (standard deviation in parentheses)					
	1996-2001		2002-2004		2005-2007	
	high irrigation service level	low irrigation service level	high irrigation service level	low irrigation service level	high irrigation service level	low irrigation service level
Hebei	-	-	-	-	15,420	79,180
	-	-	-	-	(24,196)	(283,276)
Henan	-	-	11,916	8,103	147,636	-
	-	-	(16,851)	(24,784)	(138,844)	-
Ningxia	71,890	138,729	43,690	37,501	123,869	97,603
	(133,525)	(199,485)	(150,010)	(98,587)	(271,504)	(310,550)

*irrigation service level measured as the share of actual irrigated land as a portion of intended irrigated land (high= greater than 75%)

Data source: Northern China Irrigation Management Survey, Center for Chinese Agricultural Policy, Chinese Academy of Sciences

3.4.2.2. Water availability and irrigation investment behavior

Another hypothesized driver of irrigation investment for village collectives and farmers is water supply uncertainty (see section 4.3.2.). When managers were asked to assess their village's water reliability, respondents indicated that water resources are decreasing in northern China's villages. 60% of respondents in Hebei said that water was relatively scarce and constrained agricultural and non-agricultural production. Responses in Henan and Ningxia were slightly less dire, with the majority of respondents indicating that water resources were sufficient in the short term, but shortages could become a problem in the future.

A major difference in irrigation system characteristics between villages is the availability and use of alternative water sources, including rain water and groundwater. In Hebei, only 24% of villages rely exclusively on surface water for irrigation. In contrast, 81% of villages in Ningxia only use surface water resources.

To assess the relationship between villages' investment, water resource conditions and economic activity, t-statistics measuring correlation are calculated. T-tests indicate a strong relationship between the presence of investment, from all sources, and a village's sole reliance on surface water to irrigate crops (Table 6). There is also a strong correlation between a village's surface water irrigated area and the presence of investment from each of the three sources, where larger irrigated area is associated with investment by each of these three investment sources. The number of years where there is no water in the village-level (tertiary) canals and village collective and upper-level government investment are also positively correlated. Percentage of irrigated land for cash crops is positively correlated with presence of private investment, indicating farmers are making a rational investment decision to improve the water delivery systems in order to secure water supply for higher value crops.

Table 6 Land and water resources for villages with presence of private, village public, and/or upper-level public investment

	private investment (n=46)		village investment (n=92)		upper-level investment (n=58)	
	yes	no	yes	no	yes	no
	mean	mean	mean	mean	mean	mean
Resource endowment						
Dummy of irrigates with surface water only:	0.609	0.307	0.580	0.240	0.685	0.2717
t=	3.9181***		5.561***		5.92***	
Area irrigated by surface water (ha / village):	3532.3	2404.4	3714.0	1984.8	4136.6	2179.2
t=	2.947***		5.800***		5.678***	
Has drought in last year (dummy=1 if yes):	0.435	0.396	0.420	0.393	0.444	0.391
t=	0.482		0.410		0.698	
Number of years (in last 3) with no water in canals:	0.870	0.887	0.693	0.993	0.537	0.984
t=	0.094		1.9845**		2.572**	
Agricultural Economy						
percent of irrigated land for cash crops:	0.238	0.187	0.197	0.197	0.140	0.214
t=	1.273*		0.0016		1.965**	

Data source: Center for Chinese Agricultural Policy, Chinese Academy of Sciences
Notes: Levels of statistical significance P>|t|:*=0.001, **=0.05, *=0.10, absolute value of t-statistic reported.

While investigating what explains the rising trend of private investment into surface water irrigation infrastructure in northern China’s villages, different pictures emerge of villages with and without private investment (see Table 7). Looking only at villages with private investment in 2008, the 20 villages with private investment, on average, have a strong economic base including higher village enterprise income and local incomes. Land and water resources are also different in villages with and without private investment. Villages with private investment report that in 1.29 years (out of the last 3) there was a period of no water in the canals, compared with only .93

years for villages with no private investment. These statistics, along with the exclusive reliance on surface water sources for irrigation, suggest that water supply availability does influence private investment decision making. Other social and land resources indicators are relatively similar between the two groups of villages.

To further what determines investment for various investment sources, multivariate analysis is utilized in chapter 4.

Table 7 Characteristics of villages with and without private investment into surface water irrigation infrastructure, 2008

	Without private investment (50 villages)	With private investment (20 villages)
Demand Side Factors		
Income per capita (real 2000 RMB)	2,449	3,976
	(986)	(2,966)
Village Enterprise Income (real 2000 RMB)	4,009	11,073
	(18,397)	(43,897)
Population	1,055	1,048
	(756)	(458)
villagers with greater than middle school education (%)	50.1	47.2
	(21.31)	(24.80)
Number of different crops grown	3.94	3.50
	(1.02)	(1.10)
branch and tertiary canal length (meters)	8,299	24,957
	(12,387)	(36,621)
Distance from county urban center	5.99	5.43
	(12.14)	(3.43)
Land & water resources		
number of years in past 3 without water in canals	0.93	1.29
	(1.34)	(1.40)
surface water use only	0.25	0.60
	(0.44)	(0.50)
Non-collective irrigation management	0.40	0.90
	(0.49)	(0.31)
Sown area per capita (hectares)	3.04	3.75
	(1.89)	(1.79)

Data Source: 2008 *Northern China Irrigation Management Survey;* Mean value reported, standard deviation in parentheses

3.4.3. Assessing impacts of shifting levers of village irrigation fiscal and water planning authority in northern China

Based on the *NCIM data*, in this section describes shifts in fiscal arrangements in China during the study period. Alongside developments in village-level irrigation management institutions, changes are also occurring in regional water management institutions (Yang, Zhang et al. 2003; Huang, Rozelle et al. 2009) as well as village fiscal policy and regional fiscal bureaucracies (Oi 1992; Wong 1997). In light of the many layers involved in fiscal and irrigation planning policy, this study drills down into the actual decision making processes regarding irrigation fiscal and water planning practices.

Irrigation management institutions diversified and evolved considerably during the ten year study period. While traditional forms of irrigation management led entirely by the village collective leaders and the party secretaries dominated through the 1990s, after 2001, villages began adopting reformed institutions such as WUAs and contracting (Huang, Rozelle et al. 2009). In 2001, the government began promoting irrigation management reform institutions, however collective management remained the primary management style with 58% of villages using traditional management forms. By 2004, 17% of villages transitioned to WUAs, and 55% of villages used contracting to manage all or part of their irrigation canal network. In 2008, all villages in the sample in Ningxia used WUAs or contracting, and 17% of villages in Henan used contracting or WUAs (see Table 8).

Table 8 Village control over irrigation decision making, and fiscal account information, 2008

	Unit	North China (n=55)	Henan (n=23)	Ningxia (n=32)
Village Authority over Irrigation Systems				
Villages with non-traditional irrigation management[a]:	%	64.3%	16.7%	100.0%
Share of irrigation revenue retained by village[b] :	%	3.5%	4.9%	2.2%
% where village coordinates intra-village irrigation:	%	30.4%	12.5%	43.8%
% where village collects irrigation fees:	%	16.1%	12.5%	18.8%
Village fiscal resources [cd]				
Village total revenues				
Village-level fees (tiliu):	yuan / person	73.0	85.7	60.4
Land contracting fees:	yuan / person	31.4	17.4	45.4
Canal contracting fees:	yuan / person	3.1	0.0	6.3
Surface water irrigation fees:	yuan / person	111.8	52.6	171.0
Village enterprise income :	yuan / person	125.9	44.9	206.8
Village irrigation expenditures:	yuan / person	81.7	91.6	71.8

[a] non traditional irrigation management includes contracting and water user association

[b] shares are averages from province or all north China sample

[c] population calculated based on farmers (of working age) present in the village

[d] All currency figures normalized to year 2000 Chinese Yuan
(revenue average based on non-zero average)

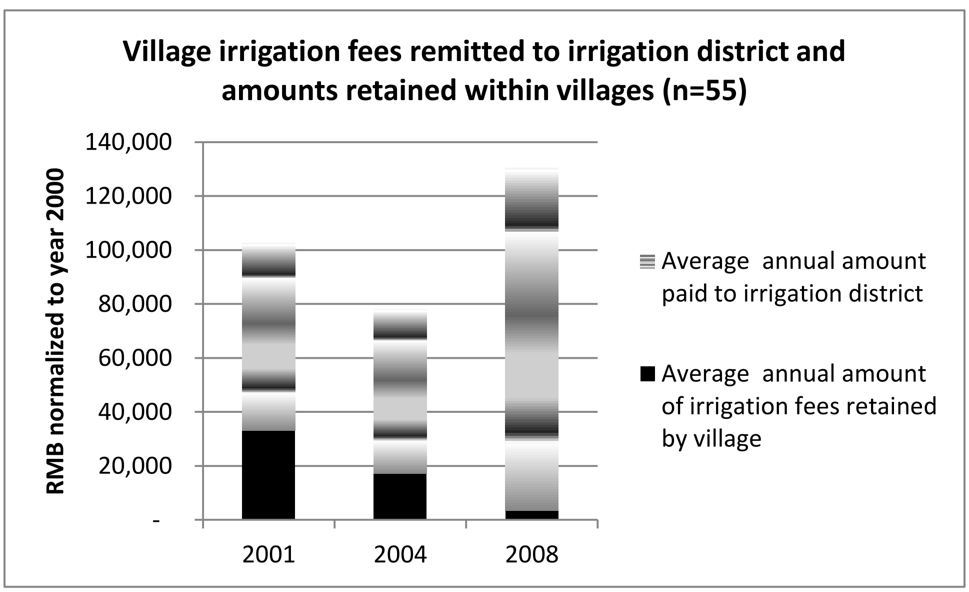
A measure of the degree of a village's fiscal authority, that is authority to generate, keep, and make discretionary choices about irrigation revenue, is the marginal retention of village irrigation revenue (MRR). Among 55 villages in the north China sample between 2002 and 2004, villages retained around 15% of irrigation fees, and submitted about 85% to the irrigation district, or other water supplier (see Table 9). In absolute terms, during this same time period, a typical village collected 102,610 Yuan in fees and submitted around 69,472 Yuan to the ID or water supplier (see Table 9). By 2008, the MRR situation changed and irrigation district bureaucracies began collecting larger shares of villages' irrigation revenue (see Figures 8 & 9). By 2008, although the total amount of fees rose, mostly due to increased tariffs, a typical village retained only 3% of the irrigation fees collected, at around 3,461 Yuan per village, a sharp decrease in retained revenue. This pattern however, is not uniform across the sample villages. Although from 2001 to 2004 the number of villages with a high MRR level remained constant at 28% of villages (16 out of 56), by 2008 only 4 villages (7%) in the sample continued to retain over 17% of irrigation fees for discretionary use by the village irrigation leadership. This shift reflects gradual policy adoption of tax-for-fee reform and the beginning of more direct provision of irrigation funding by central government agencies.

Table 9 Breakdown of share of village irrigation fees remitted to irrigation district and amounts retained within villages (n=55)

Values are RMB normalized to year 2000 RMB based on the CSB Rural CPI						
	2001		2004		2008	
	Mean	SD	Mean	SD	Mean	SD
Average marginal retention rate:	0.15	(.24)	0.16	(.25)	0.03	(.1)
Average annual amount of irrigation fees collected within village:	102,610	(143,126)	77,957	(61,214)	130,396	(106,391)
Average annual amount paid to irrigaiton district:	69,472	(67,419)	60,774	(53,114)	126,935	(105,176)
Average annual amount of irrigation fees retained by village:	33,138	(114,047)	17,183	(38,130)	3,461	(10,635)
Average amount retained by villages with high MRR:	100,675	(190,293)	41,750	(57,402)	26,231	(23,322)
Average amount retained by villages with low MRR:	2,264	(4,915)	4,081	(6,416)	1,184	(4,936)

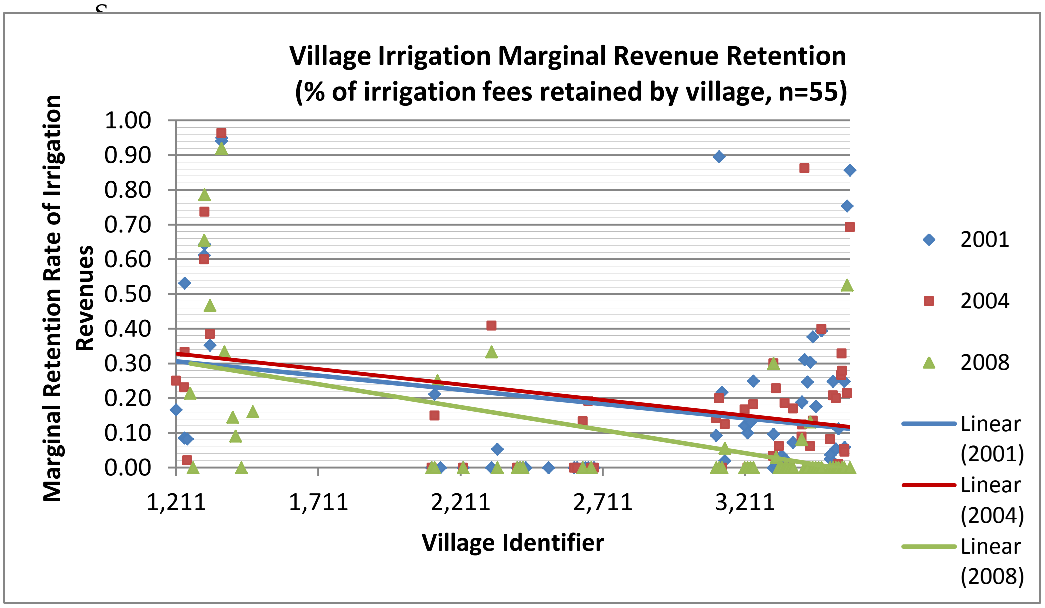
Source: CCAP, 2001 - 2008 North China Irrigation Management Survey

Figure 6: Marginal Retention of Irrigation Revenue in Northern China Villages, 2001 to 2008



Source: CCAP, 2001 - 2008 North China Irrigation Management Survey

Figure 9 Village irrigation marginal retention of revenue



Source: CCAP, 2001 - 2008 North China Irrigation Management Survey

It is reported by farmers that farmers collecting fees from farmers reduces tension between farmers and the other fee collectors (village secretary) who collect many other fees from farmers. It is also observed that by 2008, increasingly, fees go directly to the water supplier (ID) bypassing the village secretary, perhaps eliminating the possibility of skimming or mixing the irrigation budget into the general village budget (see Table 10). The direct remittance of fees by farmers to the supplier makes the trail of public fund distribution more transparent, one aim of the tax-for-fee reform. However, such facts only indicate change in the nature of the transaction, not the share of fees submitted to the ID.

Table 10 Division of fiscal responsibilities. Share of decision making controlled by person or group (n=55):

	sets village irrigation fees			collects farmer fees			settles village irrigation account		
	2001	2004*	2008	2001***	2004***	2008***	2001	2004	2008
contractor	-	-	-	31.8%	35.4%	19.6%	-	-	-
irrigation district	47.1%	52.1%	54.3%	-	-	-	58.0%	62.5%	79.5%
village secretary (committee)	17.6%	12.5%	4.3%	31.8%	22.9%	10.9%	26.0%	14.6%	11.4%
small group leader	-	-	-	22.7%	20.8%	4.3%	-	-	-
WUA leader	-	-	-	0.0%	6.3%	23.9%	-	-	-
WUA members	-	-	-	0.0%	2.1%	30.4%	-	-	-
village water manager	2.0%	6.3%	2.2%	2.3%	2.1%	0.0%	-	-	-
farmers themselves	-	-	-	0.0%	-	-	-	-	-
county or township	27.5%	22.9%	34.8%	0.0%	0.0%	0.0%	12.0%	22.9%	9.1%
other	5.9%	6.3%	4.3%	11.4%	10.4%	10.9%	-	-	-

*other=negotiation
***other=no one does it
Source: CCAP, 2001 - 2008 North China Irrigation Management Survey

In another aspect of village irrigation fiscal policy, it is observed that irrigation fee setting also changed over the study period, where village leaders and party secretaries ceded authority over setting irrigation fees to upper-levels of the irrigation bureaucracy (see Table10). Although the percentage of IDs responsible for setting irrigation fees remained constant, in around 50% of the villages, a shift took place where the village's party secretary had set the irrigation fee (18% of villages in 2001 and 13% of villages in 2004), and fee setting authority moved up the bureaucratic ladder, to the level of township or county water resources bureaus. This trend could have several explanations. First, pro-rural reforms enacted since 2000, such as "three abolitions, two adjustments, and one reform" and tax-for-fee rural reform aim to ease the burden on farmers and limit the power of village governments to levy ad hoc fees on villagers as a source of village revenue (Yep 2004).

In addition to irrigation fiscal policy, a vital component of irrigation management is accounting for the raw water resources and coordinating and planning usage among various local stakeholders, including other villages on the trunk canal system, village farmers, and other water users within the village (small businesses and enterprises). One aspect of planning, setting village allocation plans, became more concentrated in the hands of few decision makers, typically the regional water suppliers ID or township (see Table 11). While another planning task, coordinating water deliveries, remains much more grassroots with contractors, WUAs and village committees retaining responsibility over coordinating water deliveries within the village. A governance–type function, deciding on management institutions, remains a top-down policy mandate primarily decided upon by ID, county, or township.

Table 11 Division of irrigation planning responsibilities, share of decision making controlled by person or group (n=55):

	Sets village allocation plan			Coordinates water			Decides on management		
	2001	2004*	2008	2001***	2004***	2008***	2001	2004	2008
contractor:	14.3%	2.0%	0.0%	27.9%	34.9%	16.7%			
irrigation district:	61.2%	84.0%	65.9%	0.0%	0.0%	0.0%	26.1%	0.0%	25.0%
village secretary (committee):	4.1%	2.0%	0.0%	11.6%	7.0%	7.1%	13.0%	25.0%	0.0%
small group leader:	-	-	-	7.0%	7.0%	0.0%			
WUA leader:	-	-	-	0.0%	2.3%	47.6%	0.0%	0.0%	0.0%
WUA members:	-	-	-	0.0%	2.3%	9.5%			
village water manager:	-	-	-	11.6%	11.6%	0.0%			
farmers themselves:	-	-	-	20.9%	14.0%	2.4%			
county or township:	12.2%	8.0%	26.8%	0.0%	0.0%	0.0%	60.9%	75.0%	75.0%
other:	8.2%	4.0%	7.3%	20.9%	20.9%	16.7%			

*other=negotiation
***other=no one does it

These descriptions of villages' levers of fiscal and water planning authority point to general shifts in concentrations of fiscal and planning control, with a marked re-assertion of fiscal authority from villages, to IDs and counties. The impact of the shifting levels of authority remains unclear and can be better understood by using multivariate analysis (see chapter 5).

3.5. Conclusion

In addition to demonstrating a large commitment on the part of the central government to modernize northern China's small-scale irrigation systems, these data suggest that private sector involvement is also rising, and with a particular focus on investing in infrastructure to secure local water supply. Even more dramatic than the changes in the composition of local investment components however, the data shows a rapid increase in the quantity of irrigation-targeted investment funds flowing into China's villages. According to the data, total investment increased over three-fold from the 2002-2004 period, to the 2005-2007 period. The rate of project implementation since 2002 was funded by a wide range of sources, including upper-level government, village collectives and farmers. In tracking the evolution of irrigation investment in northern China's, one sees a profile of a rural economy that is in the midst of a flurry of irrigation development activity.

The tracking of investment and policy trends in China's irrigation sector reveal several clear trends. First, increased investment by the upper-level government and private sources (contractors and farmers) indicate a decisive shift from the decentralized system that characterized China's irrigation sector through 2002. Irrigation funding and management is gradually moving out of the hands of the village collective. However, the fiscal trend is not characterized by re-consolidation by the central government alone. Private investment activity by farmers and contractors is rising steadily, and is related to two observed phenomena. First, irrigation management reform has designated clearer canal ownership rights under the contract-type management system. Next, farmers that grow cash crops need a reliable water supply and appear to be willing to investment their private funds to secure water for growing higher value crops. Although such findings are based on basic statistical analysis, these provide a basis for further understanding shifts in China's irrigation development landscape.

Northern China's village-level irrigation systems can be characterized as diverse, mobilized, and yet, under performing in their primary task of conveying water to crops. What this chapter did not address is the question of why. As the previous section indicates, given the diverse composition of investment portfolios, it is unclear what factors lead to different village-level investment structures, or how these structures contribute to the observed diversity in irrigation performance outcomes. The following chapters examine in depth what factors contribute to diverse funding portfolios in northern China's villages, and next, how intra-village fiscal authority explains why some village irrigation systems perform better than others.

Chapter 4: Assessing the determinants of investment: how separate incentives drive diverse irrigation portfolios

4.1. Introduction

The goal of this chapter is to examine the determinants of local irrigation investment in northern China between 1998 and 2008. This is accomplished in two ways. First by reviewing the literature on determinants of irrigation investment from three scales: upper-level government, village collectives and farmers. Next, based on the hypotheses derived from the literature, this study uses detailed village-level fiscal and water resource data to assess drivers of development for each of the three above mentioned sources in northern China's villages. Further, this study assesses in which cases farmers follow conventional patterns and relies solely on upper-level investment funds to build local irrigation systems, or alternatively, in which types of villages farmers contribute private funds for irrigation infrastructure upgrades.

This study has two specific objectives. The first aim is to examine the reasons underlying diversity in village-level surface water irrigation investment portfolios. To accomplish this, descriptive statistics are presented to describe how progressive investment policy, water supply uncertainty and economic base explain variation in irrigation investment between villages in the study area. Next, this study aims to identify and measure the determinants of the magnitude and sources of village-level investment into irrigation infrastructure. To accomplish this, several multivariate models are specified based on the hypothesis that different investment sources have different underlying incentives driving the investment.

The rest of this chapter is organized as follows. The next section reviews existing literature on determinants of village-level irrigation investment according to the investment source – central government, village collectives and farmers. Following this, research questions are hypotheses are presented. The following section assesses the determinants of village-level irrigation investment using descriptive statistics to probe the connection between various investment sources and explanatory variables of interest. Next, measures and models for the analysis are presented. In section 4.5, multivariate models of village-level investment sources and magnitudes are estimated, and the results of econometric analysis presented. The chapter concludes with a discussion of the results.

4.2. Literature review - Determinants of irrigation investment from different sources

This literature review summarizes the global literature on determinants of irrigation investment, according to the scale of investment, central or national government, local government and private (farmer). The literature included in this review specifically examines differences in investment behavior by public and private sectors, but further scrutinizes changes in investment behavior under different degrees of centralization. Although in a decentralized fiscal system local governments hold responsibility over local public works, in China, as in many nations, national governments remain primary investors into irrigation infrastructure development, despite the formal fiscal system.

Increasing investment into irrigation infrastructure is one policy response of the government to remedy water shortages by increasing irrigation water-use efficiency. Despite large central government investments and mandates to local governments to improve irrigation systems, little agreement exists as to why local irrigation infrastructure remains in such disrepair (Feder, Lau et al. 1992; Lohmar, Wang et al. 2003). Scholars attribute the current state of China's irrigation infrastructure disrepair to large cuts in the national budgets for irrigation funds (Wang, Ren et al. 2000), local fiscal constraints (Lohmar, Wang et al. 2003) and lack of clear ownership of network canals (Lohmar and Wang 2002) following the 1978 reforms. Increasing financial pressure at the local level, combined with inefficient management, have likewise been identified as two of the major sources of problems related to under provision of irrigation systems (Tang 1992). Given that China's major food grains are mostly irrigated by surface water (Jin and Young 2001; Huang, Rozelle et al. 2006), maintaining functioning irrigation works is critical to maintaining a productive agricultural sector (Huang, Rozelle et al. 2006).

4.2.1. The role of central and national governments in public irrigation investment

Central governments are the main contributors to irrigation systems worldwide and in China (Briscoe 1999). Despite annual global expenditures of around US$ 36 billion annually into irrigation development (IEG 2006b) (pg 8), observers note that irrigation investment record keeping is poor and most nations consider irrigation investment a poverty reduction measure, and therefore do not track irrigation investment performance (Briscoe 1999). Although the international record on irrigation investment is mixed, recent findings affirm irrigation's role in reducing poverty (Huang, Rozelle et al. 2006; IEG 2006a), increasing agricultural productivity (Fan, Zhang et al. 2002) and maintaining food security (Huang, Rozelle et al. 1999).

A few notable studies attempt to make sense of nation-level irrigation investment. A study of national irrigation investment in the Philippines examines how economic and social forces induce public irrigation investment. Authors Hayami and Kikuchi hypothesize that irrigation development by the National Irrigation Administration is guided by rational criteria of long-term social profitability of investments measured as: benefit-to-cost ratio of productivity to investment measured via the *long-run calculation of improvement of land quality relative to increasing cost of expansion of cultivated land area*, and *the return on investment of increased agricultural productivity due to irrigation modernization* (Hayami and Kikuchi 1978). Their findings indicate that investment in irrigation as a means to augment cultivated land quality is more profitable than investment in expansion of cultivated area by expanding irrigated land area. Although findings from this study lack of longitudinal data to calculate the long-term costs and returns for investment in opening new arable land over time, this study provides evidence that irrigation development should consider rehabilitation of existing irrigated land in a targeted irrigation development strategy, not simply targeting all funds toward expansion.

Although no national level irrigation investment studies exist for China, one can infer from other public investment studies that in China, as in many nations, the central government uses levers of fiscal policy as a tool by which to administer state irrigation and water conservation policies (Oksenberg and Tong 1991). China's central government sets policy agendas through Five-Year Plans, and administers a central government budget to coordinate and financially support implementation of Five-Year Plan policies in the provinces. Given the wide umbrella of contributions of irrigation to rural and national welfare including, food security, poverty alleviation and economic development, tracking explanations for national level irrigation investment is not straightforward. Within the last decade in China, increasing attention has been placed on evening the rural-urban divide via rural development policies and investment (11^{th} Five Year Plan) including large levels of national investment for agricultural water conservation and management programs. Increasing attention has also been placed on curbing environmental and natural resource degradation and securing China's food supply via agricultural modernization (Huang, Rozelle et al. 1999; Zhang, Luo et al. 2006), yet the policy strategies behind these efforts have not been carefully examined.

4.2.2. Determinants of sub-national public irrigation investment

Explanations of sub-national investment decision making include several scales of investment decisions including: state, province, county, and village investment-making frameworks. Within this group of studies, several explore different forms of *local government accountability* to explain public investment distribution. Alternatively, a burgeoning literature in local fiscal policy examines channels of investment in the context of evolving fiscal and political systems where localities assume primary responsibility over local public goods provision. Although work on both topics is vast, this review is limited to works that focus on irrigation infrastructure specifically, or include irrigation infrastructure within a larger discussion of rural public goods provision.

A study of public investment in Bolivia, before and after fiscal decentralization, uses objective measures of local need for water and agriculture infrastructure to evaluate how socio-political and administrative factors determine investment decision making by central and local government levels (Faguet 2002). Faguet finds that the responsiveness of leaders to local needs and knowledge of local ecological characteristics, along with greater attention to maintenance and operations, increases the provision of service associated with infrastructure projects (Faguet 2002). Faguet also finds that the distribution of funds toward less-productive sectors decreased when controlled by local governments. The findings contribute to a growing literature on public investment allocation under different fiscal structures. Though there is wide debate on the merits of local versus central investment decision making, Faguet's findings support the theory of local corporatism in China (Oi 1992), wherein local governments focus upon local economic development needs, higher productivity (income enhancing) economic infrastructure projects (roads, electricity, education), while neglecting lower priority sectors such as agriculture or tourism.

Notably in the Bolivia study, poorer local governments received little to no investment funds from the central government, and continue to invest little post fiscal decentralization.

Another group of studies focuses on the relationship between public investment and local fiscal policy in rural China. Economic reforms across China in the late 1970s redistributed fiscal decision-making authority from the central government to lower levels of China's bureaucracy (Lieberthal and Lampton 1992). Processes over decision-making and allocation of resources, both monetary and natural resources, devolved to provinces, counties, townships and counties which often had competing development priorities (Schroeder 1992). Focusing on the composition of local economic activity in rural China, studies identify *village-level economic diversity* as the main determinant of a village's ability to provide public goods supporting agriculture, including irrigation and drainage projects. Local economic diversity in the form of a local industrial base, and hence a higher local tax base, allows village collective governments to re-distribute funds (Tam 1988; Oi 1992; Wong 1997) toward infrastructure projects. However, funding irrigation remains a low priority investment option since returns to agricultural investments are lower than industrial returns, and increased agricultural tax receipts (if agricultural productivity rises) do not go to the village (Oi 1992).

Recognizing the diversity of local economic activity as contributing to higher levels of local public goods provision, Dong *et al* investigates what happens in less industry-developed rural communities in China, where lack of industrial tax base has led to the decline of agriculture infrastructure (Dong 2000). Dong categorizes villages according to types of economic activities, and looks to see how *village collective activism* differentially determines the provision of village-level public goods across village types. Dong attributes low levels of investment activity to two factors. First, lack of accountability and public trust in villages without elected leaders and second, the inability of poorer villages to mobilize new revenue sources, thus contributing to a cycle of poverty within poor villages.

Within the studies of local public infrastructure provision in China, no clear picture of the determinants of village-level infrastructure has emerged. While the fiscal policy analyses focus on the structure of the local village economy, and the political economy analyses focus upon accountability of political leaders in making public investments, few of the studies examine infrastructure provision as a sum of the actions of scales of investing parties, including public and private sources. Further, none of the studies on local public infrastructure investment, to my knowledge, evaluate how uncertainty imposed by natural resource scarcity impact farmer and local government investment decision making. Nor do the studies on infrastructure provision consider how the multi-layer investment environment impacts irrigation investment decision making.

International development experience has shown that not all infrastructure investment makes a community better off and that the structure of public investment provision matters (Aschauer 1989; Berke, Chuenpagdee et al. 2008). In the following section, therefore, I explore the motivation for private investment into irrigation infrastructure and how private and public investments into irrigation development interact.

4.2.3. The role of farmers in local irrigation investment

Up to this point, given the cheap price of irrigation water in China, it has been found that farmers lack a price incentive to conserve water, and irrigation system users have yet to invest much into improving local irrigation infrastructure or installing water saving technologies (Huang, Rozelle et al. 2006). Others speculate the lack of private investment into irrigation does not relate to water conservation measures at all, but is related to land tenure insecurity in China's countryside (Watson 1989; Feder, Lau et al. 1992; Dong 1996; Brandt, Huang et al. 2002). Indeed, following transition to HRS, observers of China's rural development noted surprise at the lack of private investment into agriculture related fixed assets (Watson 1989; Feder, Lau et al. 1992; Dong 2000) once farmers assumed responsibility for farm-level production.

Previous research explaining farmers' private investment into surface water irrigation falls into two primary academic arenas, institutional and public economics. Based on extensive field work and case studies on irrigation systems in developing countries, institutional scholars of common pool resource goods have found that under certain institutional arrangements, farmers will invest their private funds toward rehabilitating or developing shared irrigation infrastructure (Wade 1988; Ostrom 1992). Institutionalists' research into natural resource governance identifies collective action as a necessary pre-requisite for irrigation users (farmers) effectively to manage their resource system (Uphoff 1986; Ostrom 1991).

Based on the findings from the extensive institutionalists' literature on irrigation, one may ask, can collective action explain village-level private investment in China? The answer is, likely not, for two primary reasons. First, decision making over key water resource and fiscal choices in village-level irrigation systems is the responsibility of the government. Farmers lack control over basic decision making related to quantity, timing or delivery of irrigation water, thus obscuring the incentive a farmer may have to address collective irrigation development. Field work interviews reveal farmers will often prefer to wait for the government to provide investment funds rather than put forth funds themselves. Second, field work on participatory irrigation management found that Chinese farmers remain generally disenfranchised within current institutional structures (Ou, Zachernuk et al. 2004; Wang, Xu et al. 2006). Although collective action may be present in varying degrees and contribute to agricultural and social development, no compelling evidence in China points to collective action as an indicator of village irrigation investment activity.

A second school of thought regarding farmer's private investment into surface water irrigation comes from public economics, and relates to a farmer's rational assessment of infrastructure's ability to offset risks (uncertainty) involved in water resource procurement. Arrow and Lind (1970) use the theoretical example of a farmer's decision to invest in irrigation infrastructure to demonstrate their theory of appropriate levels of investment for public goods between private and public sectors. According to Arrow and Lind, for risk averse farmers in climatic uncertainty (drought), the farmers would value the project at more than the expected value of the marginal benefit of the irrigation investment, and expend their private capital toward infrastructure development, to stabilize their incomes in times of uncertainty (Arrow and Lind 1970). Although the hypothetical example on the un-even private benefits of public investments is noted, their point neglects the social value of agriculture (food supply) in that streams of benefits of irrigation only accrue as increased income for the farmer. Likewise, the opportunity cost of no irrigation would be the loss of income stability in water-short period. Social costs and benefits indeed would be pooled by the tax-paying rural and urban residents in the form of migration, famine and food security.

Feder *et al* (1992) looks at farm–level investment in China in the post-household-responsibility-system era and finds that farmers' *perception of land tenure security* impacts private investment into productive assets. Although Feder *et al* notes that in the early 1990s "alternative mechanisms for provision of public goods of the infrastructural type have not been established, public investments have suffered a decline," the study does not systematically account for levels of public investment which omits a key factor in private decision making behavior (Aschauer 1989). These findings also are limited by the cross-sectional nature of the data, which is especially troubling for investment analysis as the impact of policy decisions takes time to manifest into investment decisions and is especially troubling for investment analysis as capital investments are lumpy in nature and a single time period neglects local or regional investment cycles. For the case of irrigation development, the investments are not into privately held land, but into shared canal networks, therefore subject to different set of investment behavior theories (Ostrom 1992).

Dong (1999) disputes Feder's view explaining the dearth of private investment and notes that other factors such as *small farm size* where large capital investment in non-divisible equipment (such as farm animals, water pumps, and tractors) inhibit private investment, and also notes low profitability of agricultural production and access to credit markets, as more important factors in determining private agricultural investment. An earlier study on village irrigation financing finds the determinant of farmers' private investment into the local system depends upon whose initial investment created the system (Coward 1986). If farmers create the system, in terms of planning and labor, thereby creating a sense of ownership, they are more likely to contribute future investments into operations and maintenance. This work follows on the work of fiscal policy scholars and examines how public investment levels and uncertainty in water supply explain private investment into fixed irrigation assets at the village-level.

4.2.4. Limitations of previous research

While it is not reasonable to expect perfect consistency across a range of regions and time periods explaining the determinants of village-level infrastructure investment, this review builds a compelling body of evidence regarding the importance of the village as unit within a larger system of bureaucratic relationships that impact the investment activity of the village collective, and actors within the village including farmers, small group leaders and contractors. Exclusion of attention to targeting factors that upper-level government agencies use to allocate investment funds to villages may also explain the diversity of public investment levels, including village investment. Yet few empirical investigations have been made into how processes of decision making, at multiple jurisdictional levels, result in differing levels of investment into local public infrastructure. A handful of studies in China offer alternative explanations for why some villages receive higher levels of public investment than others. However few of these studies use an economic framework for analysis. Each of the studies relies upon cross-sectional data which makes determining the causal direction between village characteristics and investment problematic.

Another important factor not systematically accounted for in the analyses reviewed is the factor of passage of time between the explanatory variable category, investment allocation policy, and the behavior this study aims to explain, irrigation infrastructure investment. Due to lags between decision making and project implementation, investment frameworks cannot be understood in a cross-sectional framework accounting for only one period of time. Without using longitudinal data, it is difficult to establish the temporal precedence of possibly endogenous policy factors as determinants of investment allocations. Moreover, estimates from studies based on cross-sectional results have limited generalizability due to unobserved time specific factors, and cannot account for sequential patterns in targeting investment, investment decision making, and project implementation. Dynamic analysis can assess policy objectives by examining lagged impacts over multiple time periods.

The shifts in investment policy for irrigation provision can be unraveled further by looking at the irrigation investment behavior of upper-level government agencies, villages and farmers in northern China. Assuming provincial, county, village collective governments and farmers are making rational budgeting choices regarding investments into irrigation infrastructure, in addition to responding to policy directives requiring certain levels of spending, one can begin to understand variation in the irrigation investment decisions being made into irrigation infrastructure into northern China's villages. Directives from the central government and Ministry of Water Resources call for efforts to be made to equalize disparities in northern China's irrigation development with the goals of alleviating poverty in the poorest areas, installing technology to conserve water, while also increasing system wide efficiencies in massive water works systems (MWR 2006). Indeed, examination of village-level infrastructure provision at multiple investment scales, including regional public investment from provincial and county level water resource bureaus, irrigation districts, and grassroots sources, village collectives and farmers' private funds, will contribute to understanding irrigation development in China.

To examine further the determinants of village-level surface water irrigation investments, this study offers an approach that differs from those used in previous studies. First, findings on the provision of public goods in rural settings explore how issues of accountability in governance impact public good provision (Faguet 2002; Zhang, Fan et al. 2004; Tsai 2007) in terms of how the government meets the needs of the people (does supply meet demand?), but stop short of evaluating resource constraints imposed by natural resource scarcity. This study considers how changing environmental conditions factor into public and private infrastructure investment decisions. Next, unlike most studies that use a rough proxy for levels of irrigation service provision, irrigation service capacity is measured based on the surface managers' report of actual irrigated land versus intended irrigated land to gauge how close to capacity a village's irrigation service lies. In this way, the results will show if irrigation investment agencies are following a progressive investment strategy for irrigation development, and if the government is targeting villages based on equalizing disparities based on expanding the quantity of irrigated land or improving the quality of currently irrigated land. Third, this study uses a panel data set to account for sequential lags between decision making and project implementation, to establish temporal precedence of a particular policy framework leading to various investment allocation patterns. Most studies fail to do so. Finally, this study employs a fixed effect model to account for unobserved heterogeneity at the village level that otherwise may obscure the relationship between investment amount, investment source, and decision-making criteria. Estimating a fixed effect model, the analysis can estimate the change in investment levels as local conditions change over time. This will work as long as the decision-making criteria do not change as a function of time-varying omitted variables. In looking exclusively at irrigation infrastructure, and not the village's entire stock of public goods, this chapter offers a chance to explore the relationship between investment activity and infrastructure development under different water scarcity conditions.

4.3. Research questions and hypotheses

4.3.1. Research question

The primary question this chapter's study seeks to address is:

- What incentives drive different sources to invest in village-level irrigation development?

4.3.2. Hypotheses

Following the fiscal policy and irrigation management literature, hypotheses focus on understanding the relationship of progressive investment policy, water resource uncertainty, and economic activity and villages' irrigation investment portfolios. Based on the literature, this study hypothesizes that:

Targeting policies set by the government drive upper-level government investment into village irrigation development:

(H1) *Upper-level governments target villages with less irrigation infrastructure in order to equalize effective irrigated area between villages and thereby increase regional irrigation efficiency levels*

Demand-side factors drive local investment into village irrigation development, from both local governments and farmers:

(H2) *Villages facing water resource uncertainty invest in order to secure water resource access and participate in the local agricultural economy.*

In addition to public investment, this research also measures the determinants of private (farmer) investment behavior. Hypothesis 3 theorizes as to which types of villages farmers are more willing to contribute private funds toward irrigation infrastructure:

(H3) *Risk aversion related to reducing water supply uncertainty and securing participation in the agricultural economy drives private investment into fixed irrigation assets.*

In addition, other village-characteristics that may explain village-level investment portfolios are included in the assessment to understand how other socio-economic characteristics determine irrigation investment channels in villages.

4.3.3. Summary of hypotheses

To examine the determinants of village-level surface water irrigation investment and explain the enormous heterogeneity observed across villages in magnitude and source of surface water irrigation investment (Research Question 1). This study examines the hypothesis that different funding sources have different incentives to invest and uses village-level data from 1998 to 2008 associated with varying levels of irrigation investment from three different sources -- upper-level government, the village collective, and farmers -- to test these hypotheses.

4.4. Assessing the determinants of village irrigation investment portfolios

This section examines variation in levels and source of investment across village and years in the northern China sample and further examines the main explanatory factors hypothesized to determine levels of irrigation investment. The two categories of explanatory factors examined as the underlying incentives driving investment behavior are: targeting factors and demand side factors. Summary statistics for the main dependent and explanatory variables are presented for 2001, 2004 and 2008. The sources of investment aggregated for each year are also presented. Finally, the 70 villages are divided into quartiles according to their investment levels to assess how targeting and demand-side factors are distributed across the investment quartiles.

Table 12 Summary statistics for determinants of village-level irrigation investment

	2001					2004					2008				
Variables for Determinants of Investment	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Dependent Variables:															
Investment per hectare (RMB / irrigated hectare / period)	70	25	60.7	0.0	429	70	7.0	22.4	-	167	70	23.0	59.1	0.0	373
Presence of private investment into surface water infrastructure development (dummy, 1=yes)	70	0.19	0.39	0.0	1	70	0.13	0.33	0.00	1.00	70	0.25	0.44	0.00	1.00
Targetting variables	70					70					70				
Irrigation Service Capacity (% of Irrigated land actually served)	70	0.77	0.30	0.02	1.00	70	0.77	0.31	0.19	1.28	70	0.49	0.45	0.00	1.00
Income per capita (2000 RMB / person)	70	1441	749	297	3271	70	1574	854	286	3432	70	2807	1834	492	15748
Demand side variables:															
Surface water only (dummy, 1=yes)	70	0.36	0.48	0.00	1.00	70	0.38	0.49	0.00	1.00	70	0.36	0.48	0.00	1.00
Sown area per capita (hectare / person)	70	3.34	1.57	0.98	7.64	70	3.24	1.62	0.80	9.50	70	3.26	1.95	0.79	9.20
Number of years (in last 3) with no water in canals	70	0.11	0.49	0.00	3.00	70	0.37	0.82	0.00	3.00	70	1.17	1.38	0.00	3.00
Village Enterprise Annual Income (in 1,000 real 2000 RMB)	70	2	5.70	0.00	29.70	70	10.0	75.0	0.0	667	70	5.2	26.2	0.0	197
Leadership:	70					70					70				
Cadre leadership of irrigation water operations (dummy, 1=yes)	70	0.16	0.37	0.00	1.00	70	0.36	0.48	0.00	1.00	70	0.14	0.35	0.00	1.00
Non-collective irrigation management (dummy=1 of yes)	70	0.38	0.49	0.00	1.00	70	0.65	0.48	0.00	1.00	70	0.51	0.50	0.00	1.00
System size (meters of canal)	70	7920	13183	0.00	99400	70	9667	14917	0	99400	70	12807	22310	0	166000
Other Controls:															
Number of laborers in village	70	818	448	154	2340	70	866	466	160	2200	70	1054	697	200	3800
Share of population that graduated from middle school (%)	70	45	18.1	10.0	89.0	70	46.4	22.7	1.7	92	70	48.6	22.6	8.0	93.0
Distance to county urban center (km)	70	19	16.7	1.0	100	70	19.3	16.7	1.00	100.0	70	6.2	11.2	0.0	100.0

Source: CCAP, *NCIM data set*

An average village in this sample in 2008 is located in Ningxia and invests 23 Yuan per hectare per year into surface water irrigation infrastructure. This village has had no water in its canals for 1.17 of the last three years and therefore can only irrigate 49% of the intended irrigated area. This village also uses groundwater to irrigate its land. This village likely has either a contractor or WUA managing its canal network which includes 12,807 meters of canal. A farmer in this village makes 2,807 Yuan per year and farms 3.26 hectares of land.

Summary statistics for the determinants of investment dependent and explanatory variables (see Table 12), indicate high levels of fluctuation in mean investment levels between the survey years. Whereas investment per hectare reaches 25 Yuan per hectare per period in 2001 and 23 Yuan per hectare per period in 2008, it declines to only 7 Yuan per hectare per period in 2004. Although the rate of total investment changes between survey periods, the presence of farmer investment did not vary as much from year to year, reaching as high as a mean of 25% in 2008, and a low of only 13% of villages having presence of private investment in 2004.

The main targeting variable of interest, *irrigation service capacity* remain steady at 77% in 2001 and 2004, indicating that the average percentage of intended irrigated area actually receiving irrigation services is 77%. This average drops to 49 % by 2008. Such a pattern suggests that actual irrigated area, as a share of intended irrigated area, is decreasing. This could be due to water shortages or lack of infrastructure to bring water to the previously irrigated areas. A measure of irrigation water reliability, *number of years in the last three with no water*, increased year by year throughout the study period. In 2001 the average portion of a year without water in the canals was .11 years (40.15 days), compared with 1.17 years in 2008 (427.05 days). This indicates increasing unreliability of the surface water system to provide water to crops. Two economic measures, *village enterprise income* and *per capita farmer income* also changed considerably during the study period. Village enterprise income peaked in 2004 at an average of 10,000 Yuan per village, but decreased to 5,200 Yuan per village by 2008. On the other hand, per capita farmer income peaked in 2008 reaching an average of 2,807 per farmer, an increase of almost 100% during the 7-year period.

Another source of variation between villages and between years is the composition of investment. Table 13 below tallies the different investment composition profiles for the sample villages during each survey period. The most common investment portfolio in the study period was found in 2001 and 2004 and includes upper-level government and the village collective as comprising the village irrigation investors. This portfolio type changed after 2004, declining from 31 (44.2%) and 24 (34.2%) villages having this portfolio type in 2001 and 2004, to only 8 (11.4%) villages in 2008. Following this portfolio type, the next most common portfolio is *no investment* into irrigation development. The *village and private investment portfolio type* did not vary much between years, ranging from 7 to 9 during the study period. Private investment by farmers and contractors is rarely the only investment source, but rather private investment accompanies village or government investment activity. Although this chart illustrates both the changes and diversity in irrigation investment portfolios, what drives these different portfolio types remains unexplained.

Table 13 Investment sources for surface water irrigation infrastructure

		Year		
investment source		2001	2004	2008
Upper level public investment only		4	4	6
Upper and Village Public Investment only		31	24	9
Village Public Investment only		8	9	8
Village Public and Private investment only		8	7	9
Private Investment only		0	0	1
Upper and Private Investment only		1	0	0
Upper, village public, and private investment		6	3	11
no investment		12	23	26
		70	70	70

Source: CCAP, *NCIM data set*

Table 14 Relationship between level of irrigation investment and village factors, 1996-2007

		target factors			demand factors				
Irrigation investment level	mean investment per level (year 2000 RMB)	irrigation service capacity (share)	has drought (dummy =1 if yes)	per capita income (year 2000 RMB)	share of non-ag workers in village	number village enterprises (#)	sown area per capita (ha)	use surface water only (dummy =1 if yes)	water scarcity (# of years in last 3 with no water in the canals)
Bottom 25%	5,941	0.816	0.211	1,424	55%	0.895	2.231	0.105	1.15
3rd 25%	24,023	0.746	0.241	1,878	36%	2.103	2.933	0.276	1.10
4th 25%	90,238	0.964	0.214	1,887	31%	3.679	3.361	0.357	0.57
Top 25%	567,697	0.999	0.536	2,345	39%	3.464	4.743	0.607	0.22

To further examine the investment characteristics of different types of villages, the 70 villages are subdivided into quartiles based on each village's level of irrigation infrastructure investment (see Table 14). Villages in the top 25% of levels of investment average 567,697 Yuan total investment between 1996 and 2007, while villages in the bottom 25% average only 5,941 Yuan in total investment over the 11 year period. Based on the irrigation investment level quartiles, the means of the main explanatory factors are measured for each investment quartile to assess how investment and various factors are related. The descriptive results for the targeting variables, *irrigation service capacity*, *drought* and *per capita income* suggest a non-progressive investment pattern. A village's capacity to irrigate its intended irrigated area follows closely and in a positive direction with a village's irrigation investment level. Assuming the majority of funds come from upper-level government sources, such a pattern indicates a non-progressive investment strategy for equalizing irrigation capacity between villages. 53.6% of villages in the top investment group report having a drought and also have the highest income per capita, at 2,345 Yuan per capita compared with 1,424 Yuan per capita for villages with the lowest amount of irrigation spending.

On the demand side, the per-quartile analysis reveals that villages in the highest investment bracket have larger land endowments per farmer, at 4.74 hectares per capita. Interestingly, different from the reports of drought, a villages' level of water reliability is negatively associated with the level of investment. That is to say, a higher level of water reliability is associated with the higher investment villages. As this descriptive analysis does not breakdown the source of investment, further multivariate analysis is needed to unpack how these characteristics drives village investment portfolios.

4.5. Multivariate models assessing the determinants of irrigation investment

Several arguments explaining irrigation investment patterns have been raised by observers of China's irrigation development, but there has been a lack of empirical research based on village-level data to assess their validity and importance. Although descriptive statistics provide a starting point for unraveling explanations behind the diversity in northern China's irrigation investment landscape, they do not provide conclusive or consistent explanations. For more in depth analysis, this section develops several multivariate models.

Based upon a review of the irrigation development literature, this study poses that differential public irrigation investment levels in villages is a result of policies aimed at equalizing surface water irrigation service capacity. This study also assesses how village water shortages and a diversified village economy drive local level irrigation infrastructure provision – from both the village collectives and farmers. Measures are categorized as targeting factors, for the underlying incentives explaining upper-level government investment, and demand-side factors, for the incentives driving local investment.

4.5.1. Variables and measures

4.5.1.1. <u>Dependent variables: Magnitudes and share of investment per source</u>

Multivariate analysis will be conducted using three different types of dependent variables measuring investment (see Table 15 below). For determinants of levels of total village investment, a continuous variable *irrigation investment per hectare*, is used during three time periods (1998-2001, 2002-2004, and 2005-2007). Next, to assess the determinants of the share of investment from different sources, *upper-level investment as percentage of total* and *village collective public investment as a percentage of the total investment*, is used for each investment period. A disaggregated investment variable is used next to explore what determines the magnitude of investment from various sources. To accomplish this, a log of investment for upper – level and village collective investment, is used for each period. For determinants of the willingness of farmers to invest private funds, a dichotomous variable *private investment* is used to identify if any form of private investment into surface water irrigation was made during the time period.

4.5.1.2. <u>Explanatory Variables: Targeting and demand side determinants</u>

<u>Targeting factors: A progressive investment policy for irrigation development?</u>

A recent village-level study of rural investment in China examined heterogeneity of investment, from upper-level and village-level sources, in villages throughout China. In looking at targeting factors, or village characteristics that make a particular village more attractive for receiving upper-level investment funds, the study found that China's commitment to an emerging progressive investment strategy became apparent in the early 21st century (Zhang, Luo et al. 2006). That is to say, the rate of upper –level investment into poorer villages rose higher than funding to richer villages.

But, what does a progressive investment strategy for irrigation look like? To achieve stated goals of increasing agricultural yields, while using water more efficiently, recent policy documents indicate that instead of continuing to expand effective irrigation area per the goals of pre-2007, focusing investment efforts on rehabilitating currently irrigated areas will lead to greater efficiency in both land and water use in northern China (Cai 2010). It is unclear at this point whether investment funds target increasing the quantity of effective irritated area, or the quality of irrigation works on currently irrigated area.

Given the changing definitions of progressive investment policies for irrigation development, this analysis investigates how China's progressive investment policy works for irrigation investment. Indeed, to spur agricultural productivity and increase standards of living in rural areas, increasing irrigated area has been a central goal of local and national water control policy (Huang, Rozelle et al. 2006), but the investment processes by which the government is achieving this goal are not well understood. To understand if a progressive investment policy is driving China's irrigation investment strategy, this study assesses how funds are reaching less irrigation developed areas and next, how funds are reaching more water scarce areas.

To measure a village's irrigation service capacity level, this study draws on previous work on irrigation service, measured as the ratio of irrigated land to cultivated land, (Hu, Huang et al. 2000; Huang, Rozelle et al. 2006), but base the measure for this analysis directly on surface water managers' annual accounts of *actual irrigated area within their village, as a percentage of intended irrigated area*. This aims to identify actual irrigation service capacity, not only the quantity of expanded area.

Comparison groups will be used according to high and low irrigation service capacity measured in the year previous to the data collection. *High irrigation service capacity* is defined as villages with greater than 75% of irrigated area actually irrigated in the previous year, and serves as the treatment group, and villages where less than 75% of designated irrigated sown area is actually irrigated are control villages. Within the regression analysis, the service capacity of 2001 is used as a baseline and regress a lagged *high irrigation service capacity* variable on the investment dependent variable for years 2004 and 2008. This research design is used to assess if villages with greater need to improve their irrigation services receive higher levels of investment in the subsequent period.

Other targeting factors include *per capita farmer income* as a measure of farmer's livelihood and the village's *drought status*. Water resource scarcity also impacts government decision making based on government's responsibility to respond to calamitous events (such as a drought or flood) to reduce food production disruptions and avoid income loss (Besley and Burgess 2002).

Demand side factors: Local water resource uncertainty and economic activity

Previous research indicates that irrigation user investment will increase in order to reduce supply uncertainty, under certain institutional conditions (Arrow and Lind 1970; Wade 1988). To measure a village's water supply uncertainty, this study uses surface water managers' reports of two water availability measures: *number of years in the last three with no water in the canals* and *reliance on only surface water* to understand how village-level government and farmers alter their investment patterns based on levels of water scarcity. Reliance on surface water indicates whether or not the village relies exclusively on surface water, instead of conjunctive use of surface and ground water sources. Reliance on one source of water is hypothesized to increase water uncertainty risk. Based on previous work indicating the a village's level of commercial economic activity drives local public investment (Dong 2000), annual village enterprise income is used to measure village commercial activity.

Village-level controls

Other control variables included in the models include management characteristics including irrigation management type and whether or not the irrigation manager is a cadre. To control for land resources, the analysis includes variables for wheat yields, canal system size (meters of canal length) and sown area per capita in the village. The analysis also controls the number of laborers in the village, percent of villages with greater than middle school education and distance from an urban center. For the sake of parsimony, hypotheses for significant factors will be discussed in the results section.

4.5.2. Methodology and Models

This section uses multivariate analysis to estimate how different incentives drive of village-level irrigation investment from three different sources in northern China. Five separate models are introduced and the methodologies for each model are described.

The models used to estimate how different incentives drive village-level irrigation investment are divided into two types (see Table 15): Total village investment models aggregate all investment sources to estimate what drives variation in magnitude of investment in northern China. Two dependent variables, investment per hectare and a log of investment are used. The log model produces marginal effects. The next set of models decomposes village investment by sources to separate out what drive investment from upper-level government, village collective and private investors. Targeting and demand-side explanatory factors are used to explain varying levels and sources comprising a villages' surface water investment portfolio. A logit model estimate what drives private investment in villages is also specified. More detailed models specifications and methods follow this section.

Table 15 Determinants: Models, Variables, and Analytical Tools

unit of analysis: village			
Model	Dependent Variable (s)	Key Independent Variables	Analytical Tool
Total village investment models:			
Investment Magnitude Model	total irrigation investment per hectare	▪irrigation service capacity ▪water availability	Fixed effects
Marginal Effects Model	log of total irrigation investment	▪irrigation service capacity ▪water availability	Fixed effects
Decomposition models:			
Village Investment Share Model	village investment, as % of total	▪resource mobilization ▪wateravailability*ag. economy	Random effects tobit
Upper-Level Government Share Model	upper-level government investment, as % of total	▪irrigation service capacity ▪water availability	Random effects tobit
Presence of Private Funds Model	binary variable equal to 1 in villages with presence of farmer private investment	▪water availability ▪wateravailability*ag. economy	Conditional fixed effects logit model

4.5.2.1. Methodology for analysis of progressive irrigation investment policy

Based on the previous discussion, the link between magnitude of village irrigation investment and its determinants can be represented by the following equation:

$$I_{it} = \theta_{0t} + \theta_1 S_{it-1} + \theta_2 S_{it-1} * T_i + \theta_3 W_{it} + \theta_4 a_{it} + \theta_5 \gamma_{it} + (u_i + e_{it}) \tag{1}$$

Where village infrastructure investments per hectare I_{it} (the per hectare normalization controls for heterogeneous village sizes) are regressed on time effects θ_{0t}, S_{it}, a dummy variable indicating if the actual surface water irrigated area is greater than 75% an irrigation service capacity measure. To account for time requirements in the provision of infrastructure, this analysis lags the key independent variable *Irrigation Service Capacity* to account for the time needed to assess and direct projects toward areas of most need. Due to the lag structure, the analysis only includes villages' *investment per hectare* for years 2004 and 2008. W_{it} is matrix of water scarcity variables including *number for years (in past 3) when the village experienced no water in the canals* and a dummy variable for *presence of a drought*, for in village *i* in time period *t*,, and a vector a_{it} of proxies of political and geographical characteristics, to identify how leadership characteristics are associated with higher irrigation infrastructure investment. γ is a vector of socio-economic controls including number of meters of tertiary and branch canals, net per farmer income, province and amount of non-agricultural economic activity. The error term for the fixed effect models is decomposed into two parts, u_i is the unobserved village-level heterogeneity for the fixed effects models, and e_{it} is the idiosyncratic error term which is assumed to be uncorrelated with any of the explanatory variables.

To estimate the difference in investment provision between villages with high and low levels of irrigated serviced area between the three time periods, the analysis includes an interaction term $S_{t-1} * T_i$, where T=2 for 2004, and T=3 for 2008.

To estimate the determinants of different proportions of investment from various sources, the analysis uses the fixed effect Tobit estimator to regress the impact of the explanatory variables listed above on U_{it} and V_{it} indicating share of upper-level government and village collective investment, per village, per period.

4.5.2.2. Methodology for determinants of farmers' willingness to invest

To estimate the factors related to the determinants of farmers' willingness to invest private funds toward irrigation development, the conditional fixed effects logistic model is preferred overall and referenced in the following discussion.[5] To explain the binary outcome of private investment into surface water irrigation system, the analysis employs a logit model to explain two outcome possibilities: villages with presence of farmer private investment and villages without presence of private farmer investment. The conditional fixed effect logit model provides a way to estimate the effects of independent variables on a dichotomous outcome variable when the observations are grouped, and group membership affects the outcome (Chamberlain 1980). In this case, villages serve as the grouping unit, farmers within the villages exhibiting a willingness to invest private funds into surface water irrigation infrastructure serves as the group outcome. The following model is specified a model to estimate the probability that a village has farmers willing to invest private funds:

$$\text{Logit}(p) = \log\left(\frac{p}{1-p}\right) = \log(p) - \log(1-p) \tag{2}$$

using the equation:

$$\text{logit}(p_{it}) = \beta_1 + \beta_2 G_{it} + \beta_2 W_{it} + \beta_3 Z_{it} + \beta_2 D_{it} + (\mu_i + \varepsilon_{it}) \tag{3}$$

Where p_{it} represents *the probability of a positive outcome (p=1) for private investment* for a village *i* in time period *t*. G_{it} represents my matrix of economic diversity terms including crop diversity, percent of worker in village state-owned

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[5] Results of a Hausman Test for model specification between fixed effects and pooled logit report with high probability, that the differences in coefficients are not systematic, by failing to reject the null that ρ=0. (chibar^2(01)=8.01, p(ρ=0)= 0.452) This indicates a preference for the conditional fixed effects logit model.

enterprise, number of people in the workforce, and per capita income. W_{it} is matrix of water scarcity variables including number for years (in past 3) when you experienced no water in the canals and a dummy variable for presence of a drought, for in village *i* in time period *t;* Z_{it} a matrix of control variables that represent other village factors affecting irrigation system performance. Specifically, the analysis includes a number of variables to hold constant the village's land resources, irrigation system structure and village socio-demographic characteristics.

The analysis assumes the idiosyncratic error term ε_{it}, is uncorrelated with any of the explanatory variables or the dependent variable. This logit model estimates the odds ratio using a conditional fixed effects model, where I can control for village-level heterogeneity contributing to the presence of private investment in the term μ_i. The model's odds ratios explain the likelihood that a village will have farmers willing to invest their private funds into irrigation infrastructure. A White Test is used to measure heteroskedasticity and do not detect heteroskedasticity (Prob>chi^2 = 0.16). Autocorrelation is detected in the model (chi^2= .029, $t_{residlag}$=4.10). To counter the presence of autocorrelation AR(1), robust standard errors are used which correct for biased standard errors and z-statistics.

4.5.3. Results

To identify the relationship between investment provision and irrigation service disparity, this analysis employ a three-wave panel data analysis of village-level irrigation systems and estimate multiple models for my dependent variables. The panel structure of the data allows us to probe differences between villages over three time periods, and within villages over the time periods. To achieve the goal of estimating village–level determinants of irrigation infrastructure provision, several estimation methods can be utilized. A standard ordinary least squares (OLS) model has several drawbacks such as producing biased parameters due to omitted unobserved heterogeneity associated with explanatory variables within villages. Similarly, an OLS model will estimate biased standard errors when the errors are heteroskedastic or dependent within a group, when there is correlation for observations within a village across time periods. When omitted time-invariant variables are correlated with the key explanatory variables, a fixed effects model will provide a consistent and unbiased estimate of the parameters while concurrently controlling for unobserved heterogeneity in each village. Alternatively, if omitted time-invariant variables are uncorrelated with the key explanatory variables, a random effects model will provide a more efficient estimate than would fixed effects[6].

In order to use the most appropriate estimator, the analysis employs an appropriate parameter estimation method based on model specifications tests including Hausman and the Breusch-Pagan conducted for the dependent variable. As for any panel dataset, the presence of correlation between subsequent error terms in either the positive or the negative direction is a likely problem, the Breusch-Godfrey method is used to test for autocorrelation in each model.

4.5.3.1. <u>Determinants of magnitude of irrigation provision</u>

[6] A chi^2 value 49.79, p=0.00001 for the test between random and fixed effect models allows us to reject the null of systematic differences between coefficients and prefer the fixed effects model. The Hausman test results verify a strict assumption of the random effects model, that the idiosyncratic error term, ε, is correlated with the explanatory variables, therefore the fixed effect estimator is preferred.

In estimating Eqn. (1) with the survey data, the econometric estimation performs well (Table 16). Most of the coefficients of the control variables have the expected signs and a number of the coefficients are statistically significant. For example, the coefficient of using surface water only variable is positive and statistically significant (Models 2 and 3, row 6). Even if the management characteristics are dropped (Model 2) econometric estimation still performs well and there are few differences among the estimation results.

Table 16 Regression analysis of the determinants of surface water irrigation provision

Dependent variable: surface water irrigation investment per hectare, t+1, t+2 using a fixed effects model				
		irrigation service capacity only, within treatment interactions	irrigation service capacity & water, no management	irrigation service capacity, with water and controls
		Model 1	Model 2	Model 3
Targeting variables				
1	High irrigation service level in 1998-2001	-7.21	40.88	41.65
		-0.37	(18.12)***	(18.76)***
2	High irrigation service level in 2002-2004	79.80	55.15	54.45
		(2.53)***	(19.33)***	(20.96)***
3	High Service * Treatment Post 2001	88.1		87.92
		(2.75)***		(2.76)**
4	High Service * Treatment Post 2004	9.67		20.61
		(0.11)		(0.48)
5	per capita farmer net income (RMB/ person)		0.00	0.00
			(0.01)	(0.00)
Demand Side variables				
6	Use only surface water to irrigate (dummy = 1 if surface water only)		72.81	73.43
			(26.44)***	(27.24)***
7	Number of years with no water in the canals		5.56	5.13
			(6.25)	(6.44)
8	Sown area per capita (ha/person)		0.51	0.97
			(5.27)	(5.53)
9	village enterprise annual real income (RMB)		0.00	0.00
			(0.00)	(0.00)
Management Characteristics				
10	Surface water manager is cadre (dummy=1 if yes)			-10.17
				(20.14)
11	Non collective management (dummy=1 if non collective management)			-8.67
				(15.75)
Basic Irrigation Conditions				
12	log of meters of canal in village (meters)		6.45	10.46
			(23.14)	(25.05)
13	gross irrigation infrastructure through previous		0.00	0.00
			(0.00)	(0.00)
Other Control Variables				
14	Annual wheat productivity (kg / ha)		-0.02	-0.01
			(0.01)	(0.01)
15	log distance from village to county capital (km)		-3.16	-0.73
			(6.32)	(7.78)
16	Share of workers that graduated from middle school (%)		-0.05	0.00
			-(0.28)	(0.29)
	R^2	0.27	0.47	0.48
	observations	140	140	140
	villages	70	70	70
	F - joint sig of X	5.92***	3.03***	2.54***
	F - joint sig of villages	1.71**	1.80**	1.71**

Data source: CCAP, Northern China Irrigation Management Survey.

Notes: absolute value of t statistics in parentheses. Levels of statistical significance P>|t|:*=0.001, **=0.05, *=0.10; Constant not shown in table for parsimony. Year dummies for 2004, and 2008 not shown in results; constant not shown for parsimony

Results from the regression analysis indicate that irrigation service provision in northern China's villages is not being equalized, but rather that villages with high levels of functioning irrigation serviced area continue to have higher investment than villages with lower levels of surface water irrigation capacity. From the results, one can see that within the group of villages that attained a high level of irrigation service capacity during this ten-year period, a village with high level of irrigation serviced area between 1998-2001 will invest, on average, in 2002-2004, 88.10 RMB per hectare, more than a village that had low-serviced area between 1998-2001, holding all else constant. For villages with actual irrigation serviced area greater than 75% of the intended irrigated serviced area in investment periods 1998-2001, and 2002-2004, total investment in these villages was higher than villages with low levels of irrigation serviced areas, by 42 RMB per hectare, and 55 RMB per hectare, respectively, holding all else constant. In other words, villages with high service levels are keeping high service levels, and villages with low service levels are not developing their infrastructure to be able to irrigate greater than 75% of the land intended for irrigation.

The descriptive results show that there is little movement from low level of actual serviced area, to high level of irrigation serviced area, multivariate results confirm that since high-serviced areas continue to invest significantly more funds toward irrigation infrastructure than low-service areas, irrigation service disparity will continue to exist in the countryside, despite policy objectives to equalize irrigation services across rural northern China.

Across all models, a village that only uses surface water to irrigate invests 72 RMB more per hectare into surface water irrigation than a village utilizing groundwater or conjunctive water sources, holding all else constant. For villages relying exclusively on surface water, all irrigation infrastructure investment supports surface water development, including canals, pumps, electricity equipment, as the infrastructure funds are not being allocated between groundwater and surface water irrigation development.

4.5.3.2. Determinants of irrigation investment from different sources

Although analysis of the determinants of surface water irrigation investment per village yields interesting results on the overall patterns of investment in northern China, an underlying problem with the structure of the analysis lies in the dependent variable, rate of investment per hectare, is the sum of investment from multiple investment sources. In closely looking at the explanatory factors for different sources of village investment, it could be expected that each source – village collective, upper-level government, and private investors – could have separate determinants for investing. Aggregating the sources of investment could have consequences on the underlying structure of my model. To address such concerns, in the following sections, the analysis disaggregates village-level irrigation investment in several ways. First, the dependent variable is divided into proportion of investment from upper-level and village collective. Due to the fact that in a small proportion of the villages there is a third source of investment, private farmer investment, the share of village collective and upper-level investment does not add up to one. Since the proportions do not add up to one, separate regressions are run for each of these dependent variables, and report results for each of the regressions.

The presence of private farmer investment in village-level irrigation provision is a small but rising trend across northern Chinese villages. Due to the large number of zero – private investment villages, a dummy variable is used to measure presence of private investment within the village and report results from the logistic regression. Lastly, aside from the share of investment from upper-level and village collective sources, it is also interesting to measure determinants of the magnitude of different investment sources within the villages. To accomplish this, separate regressions are run for total investment for each of the three time periods, for village collective and upper-level government investment sources.

After dividing investment by source, regression results indicate good model fit, and the relationship between several explanatory variables and share of the investment source is more precise (see Table 17). In this more precise viewing of the determinants of village-level investment, the picture becomes more vivid of government's difficulty in reaching and improving irrigation services in under-served areas. Although it would be expected that the signs on the coefficients between the upper-level government and village collective sources would be opposite, this is not always the case. In terms of targeting villages for irrigation infrastructure development, upper-level government funds throughout the ten-year study period were consistently allocated to villages with more developed surface water irrigation provision capacity. In looking to see how the village collective may respond to upper-level government investment, in 1998-2001, village collective investment in locales with high levels of irrigation service capacity dropped, while upper-level investment rose.

Table 17 Determinants of surface water irrigation investment by source, for 2001, 2004, 2008

dependent variable - share of village investment source from:	upper-level government (tobit estimator)[a]	Village Collective (tobit estimator)[a]
Demand side factors		
1 Village enterprise annual real income (RMB)	0.0000	0.0000
	(0.00)	(0.00)
2 Crop variety (number of different crops grown)	0.0938	0.2456
	(0.11)	(0.13)**
3 Sown area per capita (ha/person)	0.1470	0.0607
	(0.08)**	(0.09)
4 Log of meters of canal in village (meters)	0.1226	-0.0673
	(0.12)	(0.13)
5 Gross irrigation infrastructure through previous period (RMB)	0.0000	0.0000
	(0.00)	(0.00)
Targeting factors		
6 Per capita farmer net income (RMB/ person)	0.0001	0.0002
	(0.00)	(0.00)**
7 High level of irrigation service 1998-01	0.9347	-1.2926
	(0.39)***	(0.49)***
8 High level of irrigation service 2002-04	-0.0841	-0.0423
	(0.42)	(0.50)
9 High level of irrigation service 2005-07	1.1233	0.4852
	(0.39)***	(0.45)
10 Number of agricultural workers	0.0004	0.0007
	(0.00)	(0.00)***
11 log distance from village to county capital (km)	0.0482	0.0893
	(0.16)	(0.17)
Water Resources		
12 Use only surface water to irrigate (dummy = 1 if surface water only)	0.5858	0.7175
	(0.25)***	(0.29)***
13 Number of years with no water in the canals	0.0253	-0.1880
	(0.12)	(0.14)
14 Drought (dummy =1 if drought reported during investment period)	0.4765	0.1506
	(0.29)*	(0.34)
Other factors		
15 Share of workers that graduated from middle school (%)	0.0028	0.0007
	(0.01)	(0.01)
16 Surface water manager is cadre (dummy=1 if yes)	0.0735	-0.2266
	(0.26)	(0.30)
17 Non collective management (dummy=1 if non collective management)	0.5412	0.51
	(0.28)**	(0.31)**
Wald Chi^2	30.04** (18 dof)	29.23** (18 dof)
observations	210	210
villages	70	70

Data source: CCAP, *Northern China Irrigation Management Survey*.

Notes: a. Coefficients are marginal effect, absolute value of t statistics in parentheses. Levels of statistical significance P>|t|:*=0.001, **=0.05, *=0.10; Constant not shown in table for parsimony. Year dummies not shown in results; constant not shown for parsimony

On the demand side, land resources, measured as sown area per capita has a positive relationship with each investment source. The variety of crops grown in the village has a positive and statistically significant relationship with village collective investment into surface water infrastructure development. Villages with more agricultural expertise related to crop varieties, especially higher value crops and watering requirements may calculate surface water improvements as having a positive return on investment for non-grain, higher value crops. The number of workers in the village is an important determinant of village investment into irrigation infrastructure development. The amount of available labor for agriculture is a critical input into agricultural production, aside from other production factors including capital (infrastructure), land and raw materials. Village leaders making budgeting decisions where all critical production inputs are present will make higher investments into the capital portion of production when labor is available.

From the village collective investment determinants, more diverse crops are associated with a higher share of village-level investment than with upper-level government investment (see Table 17). These results support Oi's 1992 finding that local investments are made to support local economic development. In this case, village collective investments are made to support higher value agricultural production in the form of cash crop revenue, despite the fact that no taxes are collected on this revenue.

Water resource conditions matter more for determining upper-level irrigation investment priorities than village-level investment. Although for both sources, the exclusive use of surface water plays a determining role in investment allocation between villages, water availability also plays a role in determining upper-level investment allocation. If fact, water availability yields opposite direction of impact on investment determination between upper-level government and village collectives (Table 9, line 13). Where upper-level governments will allocate more to villages with unreliable water supply, in villages with unreliable water supply, the village collective will invest a smaller share of total investment monies. When considering the village-level and upper-level government policy priorities, this trend makes sense. Upper-level government not only makes investments to ensure economic and agricultural development, other priorities include poverty alleviation, and guaranteeing stable agricultural output throughout periods of natural disaster (including severe droughts). This finding supports previous research that found water resource scarcity impacts government decision making due to government's responsibility to respond to calamitous events (such as a drought or flood) to reduce food production disruptions and avoid income loss (Besley and Burgess 2002). Increased funding for drought stricken villages may come from targeted emergency relief funds routinely used in the case of weather related emergencies including floods, droughts, and plant disease outbreaks.

When considering the magnitude of investment by source, results support findings in the previous models, with a few notable exceptions (see Table 18). Having fewer number of workers matters for determining the magnitude of upper-level government investment but the number of workers does not matter for the magnitude of village investment. One less agricultural worker per village results in 0.20%[7] decrease in upper-level government investment over the investment period, holding all else constant (Table 10, Row 11). The number of workers is a positive and significant determinant of investment across models, holding other factors constant. Other targeting factors for investment match the previous findings and remain significant. Villages with high level of irrigation service capacity continue to have higher levels of investment than villages with lower irrigation service capacity, holding all other factors constant.

Non-collective management is positive and significant for upper-level government and village collective investment. This could be for two reasons. First, WUAs and contractors receive implementation subsidies as part of the larger irrigation institutional reform campaign. Next, institutional reform also clarifies canal rights and responsibilities and creates an incentive for investment. If improvements are made on the canal network and the contractors can collect higher fees due to improved service, better incentives are in place to spur investment.

[7] The precise percentage increase is calculated using the formula: $\%\Delta y = 100\left[\exp\left(\hat{\beta}_1\right) - 1\right]$

Table 18 Regression analysis of the determinants of the magnitude of surface water irrigation provision, fixed effects, 2001-04, 2005-07

Dependent variable: log of surface water irrigation investment quantity, by source		
	Upper-level government	Village collective
Demand side factors		
1 village enterprise annual real income (RMB)	0.0000	0.0000
	(0.00)	(0.00)
2 crop variety (number of different crops grown in village)	0.2758	0.3758
	(0.35)	(0.55)
3 Sown area per capita (ha/person)	0.0814	0.5993
	(0.28)	(0.44)
4 log of meters of canal in village (meters)	-2.6911	-0.5498
	(1.32)**	(2.10)
5 gross irrigation infrastructure through previous period (RMB)	0.0000	0.0000
	(0.00)	(0.00)
Targetting factors		
6 High level of irrigation service 1998-01	1.8991	1.7890
	(0.96)**	(1.53)
7 High level of irrigation service 2002-04	2.4942	3.4641
	(1.03)***	(1.64)**
8 Use only surface water to irrigate (dummy = 1 if surface water only)	4.07	1.24
	(1.15)***	(1.83)
9 Number of years with no water in the canals	0.2743	-0.1754
	(0.31)	(0.50)
10 Drought (dummy =1 if drought reported during investment period)	-1.1979	-0.8060
	(0.91)	(1.44)
11 Number of agricultural workers	-0.0020	0.0013
	(0.01)**	(0.00)
12 per capita farmer net income (RMB/ person)	-0.0001	0.0007
	(0.00)	(0.00)*
13 log distance from village to county capital (km)	-0.0811	0.6922
	(0.45)	(0.71)
Other factors		
14 Surface water manager is cadre (dummy=1 if yes)	-0.76	-3.64
	(1.02)	(1.62)**
15 Non collective management (dummy=1 if non collective management)	0.76	-2.19
	(0.80)	(1.28)*
16 Share of workers that graduated from middle school (%)	0.00	0.04
	(0.01)	(0.02)*
R^2	0.49	0.37
observations	140	140
villages	70	70
F - joint sig of X	2.86***	1.71*
F - joint sig of villages	3.77***	1.01

Data source: Northern China Irrigation Management Survey.

Notes: a. Coefficients are marginal effect, absolute value of t statistics in parentheses. Levels of statistical significance P>|t|:*=0.001, **=0.05, *=0.10; Constant not shown in table for parsimony. Year dummies not shown in results; constant not shown for parsimony

Interestingly, the direction of correlation between explanatory variables and the magnitude of investment by source, often works in the same direction for upper-level and village collective investment, suggesting a complementary relationship. Of note in these results is the relevance of village-level irrigation management in determining village collective investment levels. Magnitude of investment decreases when the irrigation system has a non-collective management. This result aligns with the concept of both non-collective forms of management such as water user associations and contract management to separate the finances for irrigation from the general village collective budget with the aim of cost recovery within the village irrigation system (Lin 2003). Factors such as whether or not the surface water manager is a cadre and the villages' general education level also drive village collective investment due to stronger political relationships (Zhang, Fan et al. 2004).

4.5.4. Farmers' willingness to invest private funds

Finally, the analysis assesses in which types of villages farmers, WUAs and contractors invest private funds toward surface water infrastructure development (see Table 19). These results support previous findings that in villages with greater economic diversity and higher income levels, farmers will invest private funds toward collective goods, in this case surface water irrigation infrastructure. Results indicate that villages with higher per capita income have a higher probability of farmers' willingness to invest private funds toward irrigation infrastructure, holding other factors constant.

Table 19 Determinants of farmer surface water irrigation investment, for 2001, 2004, 2008.

	determinants of private surface water irrigation investment, for 2001, 2004, 2008.		
	dependent variable: presence of private investment in village	Logit conditional fixed effects model[b]	
		(1)	*(2)*
Demand side factors			
1	village enterprise annual real income (RMB)	1.0000	1.0000
		(0.00)*	(0.00)
2	Access to credit		3.8444
			(4.58)
3	crop variety (number of different crops grown in village)	0.5297	1.2133
		(0.35)	(0.38)
4	Sown area per capita (ha/person)	1.4303	1.5722
		(0.47)	(0.74)
5	log of meters of canal in village (meters)	1.9194	1.4294
		(1.29)	(1.16)
Other factors			
6	per capita farmer net income (RMB/ person)	1.0010	1.0012
		(0.00)**	(0.00)**
7	Number of agricultural workers	1.0005	1.0006
		(0.00)	(0.00)
8	log distance from village to county capital (km)	0.7660	0.7596
		(0.43)	(0.44)
9	Use only surface water to irrigate (dummy = 1 if surface water only)	19.4523	18.787
		(1.85)**	(31.18)*
10	Number of years with no water in the canals	0.9627	0.9353
		(0.47)	(0.35)
11	Drought (dummy =1 if drought reported during investment period)	2.9551	3.9627
		(1.16)**	(3.16)*
12	Drought * surface water use only		0.0301
			(0.05)**
13	Share of workers that graduated from middle school (%)	0.9921	0.9918
		(0.02)	(0.02)
14	Surface water manager is cadre (dummy=1 if yes)	-0.6355	-0.6555
		(1.01)	(0.96)
15	Non collective management (dummy=1 if non collective management)	6.8910	17.4994
		(1.10)**	(21.49)***
	Wald Chi^2	21.40** (12 *dof*)	28.48***(14 *dof*)
	observations	210	210
	villages	70	70

b. odds ratios reported, z statistics in parentheses.
Data source: Northern China Irrigation Management Survey.
Notes: Levels of statistical significance P>|t|:*=0.001, **=0.05, *=0.10; Constant not shown in table for parsimony. Year dummies not shown in results; constant not shown for parsimony

Water resource conditions also matter in farmers' willingness to invest private funds toward irrigation infrastructure development. Within the sample, in villages across northern China, farmers react to water scarcity by investing private funds, under certain conditions. In villages utilizing only surface water resources for irrigation, farmers are willing to invest private funds toward irrigation infrastructure during drought periods, holding other factors constant. This finding supports economic theories of farmers' investment decisions under uncertainty. Water resource scarcity has been found to impact resource users' decision making related to irrigation fixed capital investment. User investment will increase in order to reduce supply uncertainty, under certain institutional conditions (Arrow and Lind 1970; Wade 1988).

These results suggest that economic conditions and lack of alternative water resources in water scarce times make farmers more likely to invest their private funds into infrastructure provision. Although this is an important finding, results over a longer time frame looking at farmers' decision making under climactic uncertainty would be needed to understand better the long –term versus short-term reactions to water scarcity.

4.6. Conclusion

Results from the determinant of investment analysis reinforce earlier descriptive results suggesting a very active yet fragmented investment activity in rural northern China. This chapter has three main findings. First, the government targets investment funds toward villages with high levels of existing irrigation serviced areas, thus focusing on increasing the quality of irrigated land in northern China but not expanding the quantity of surface water irrigated area. Second, results indicate that unreliable water supply spurs investment from two groups, upper-level government and farmers, but not from the village collective. Third, farmers are reacting to water scarcity by investing private funds into infrastructure that secures water supply, thus investing in order to increase water supply certainty and sustain agricultural yields in times of water shortage. This indicates a decisive shift in the local over power over local irrigation management in China.

Investment into China's surface water irrigation infrastructure in many cases defies conventional theory on investment into public goods[8]. Scholars of irrigation investment in lesser developed nations have found that when governments provide large capital investments in common pool goods, individuals will not contribute their personal money to building or maintaining such goods (Ostrom, 2002). In other debates exploring the relationships between land use rights and investment, it has been found that ambiguous property rights laws for both villages and individuals, increases risk associated with local and private investment into agriculture-related infrastructure (Feder, Lau et al. 1992) and leads to under-investment into high-value capital goods such as tractors, canals, and maintenance facilities. Results from this chapter indicate that in China, contrary to theory, upper –level government and private farmers are investing in irrigation infrastructure including canals lining, electric pumps, and maintenance sheds. Despite problems of chronic water shortages

[8] Irrigation systems fall into a class of public goods called common pool resources (Ostrom 1992) that are defined by 2 characteristics: 1) goods where that are difficult and costly to exclude someone from using, and 2) goods subject to the overuse of the good where one person's use subtracts from benefits available to others.

and potential free-riding within communities, farmers continue to invest private funds into irrigation infrastructure.

Chapter 5: Assesing the impacts of decentralized fiscal and water planning authority on irrigation development outcomes

5.1. Introduction

The confluence of China's changing fiscal governance (centralized, decentralized, federalism Chinese Style, etc.) and the local nature of water resources makes irrigation infrastructure investment an interesting crossroads to probe the impact of fiscal decision making authority at various bureaucratic levels on irrigation system performance. To examine the underlying fiscal processes mentioned above, this research engages the larger natural resource governance question, at what level of government are local-level infrastructure provision decisions best made? i.e. by local leaders, resource users or upper-level government agencies? And, how do irrigation outcomes differ according to who decides upon the infrastructure development and planning?

In answering these questions, this chapter aims to contribute to the understanding of fiscal and water resource planning of village-level irrigation systems in northern

China and to the larger debate on how decentralization impacts outcomes related to natural resource related infrastructure. This is accomplished in a number of ways. First, this section describes patterns of fiscal hierarchy in place for village-level irrigation management. Next, by measuring how village-level authority over irrigation investment impacts the effectiveness of irrigation development. To accomplish these goals this chapter pursues three objectives. First, this study presents an empirical framework to understand changes in village-level irrigation fiscal policy which illustrates the dual pressures of fiscal re-concentration and water resource planning devolution occurring in China's irrigation development. Second, this study documents changes in fiscal structure within and across 55 villages in northern China between 1998 and 2008 to understand the evolution of various fiscal forms, and why certain forms may exist in some places and not others. Last, this study analyzes the impacts of fiscal structure on meeting three irrigation development policy goals of: water conservation, increased crop yields and poverty alleviation. Descriptive and multivariate analyses are used to unpack how village-level fiscal structure may incentivize some irrigation activities, while impeding others.

Irrigation development efforts are cast as the product of decision-making processes of village and irrigation managers set within a village and irrigation bureaucracy framework. Conceptualizing irrigation development as a result of fiscal decision making made within a set of formal and informal institutions allows the study to bring insights from fiscal policy and political economy theories to bear on broader questions of local resource management and irrigation system performance.

Two notes on the focus of this study. First, this article does not capture the informal "politiking, bargaining and negotiating" (Oksenberg and Tong 1991) of the annual national financial and planning conferences within the Water Resource or Agriculture and Animal Husbandry Bureaus. However, in focusing upon village–level irrigation, the study can assess how levers of fiscal and irrigation policy function within villages, and separate the functional division of authority over fiscal and water resource planning decision making, as reported by village leaders and irrigation managers. Indeed, the study can capture which irrigation-related processes are under the discretionary control of villages. Second, given the importance and magnitude of agriculture in northern China, the selection of northern China as a case by which to analyze the relationship among fiscal policy, water planning and irrigation development, is both timely and necessary.

5.2. Literature Review: Decentralized decision making and irrigation development outcomes

Although little has been written on fiscal governance of China's village irrigation systems, one can piece together studies on irrigation, institutions and fiscal structure studies in China to understand general trends in China's irrigation practices and fiscal management. This first section reviews the current state of irrigation related institutions and fiscal policies in China. Next, the literature on the decentralization debate in environmental governance is reviewed.

5.2.1. State of local irrigation fiscal policy in China

In the past 30 years, irrigation decision-making processes, related to both monetary and water resources, have devolved to provinces, counties, townships and villages (Schroeder 1992; Huang, Rozelle et al. 2009). An indication of devolved decision making in surface water irrigation infrastructure provision is the observed trend toward increased local investment and project planning for irrigation infrastructure (Lohmar, Wang et al. 2003; Fan, Zhang et al. 2004). Although surface water irrigation institutions appear to be evolving toward localized control, it remains unclear where the actual locus of authority lies over village-level fiscal and water resource decision making (Huang, Rozelle et al. 2006; Huang, Rozelle et al. 2009).

Amid increasing diversity of local irrigation institutions, observers have yet to identify what has changed in functional decision-making processes related to capital investments, revenue distribution or village-level water allocation. As scholars and government officials look to scale up investment in rural infrastructure with the aim to improve incomes and sustain agricultural yields, but facing tight budget constraints, better understanding of the impact of fiscal authority on the effectiveness of public investment into irrigation development can help inform policy solutions that meet regional water conservation and agricultural development goals.

Twenty years before the introduction of irrigation management reform, China's central government began experimenting with decentralized fiscal policy by creating various revenue sharing arrangements that changed the rules for sharing of locally collected revenues (Oksenberg and Tong 1991)[9]. Under post-reform rules, local governments gained greater discretion and flexibility in deciding how to

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[9] A large literature on fiscal policy in China exists and categorizes the many different revenue sharing forms, and the impacts of such agreements in the post-reform era. For much more detailed look at China's fiscal contracting, extra budgetary revenue structure, and other experimental fiscal policies see: Oksenberg and Tong (1991),Wong (1991), Oi (1992), West (1995), Jin et al (2005), Lin and Liu (2000), Tsui and Wang (2004).

generate revenue and make expenditures (Oi 1992). The local fiscal incentive approach provided a clever way in which localities could achieve the macro-economic development goals of the central government in ways that also benefitted local governments. The underlying theory being that if local governments retain a significant portion of the increased tax revenue, they will promote economic development in order to get more tax revenue; this sharing arrangement to support market development is known as the "helping hand" approach (Tsui and Wang 2004; Jin, Qian et al. 2005). What began as a center-province fiscal system soon was mimicked throughout China’s sub-national bureaucracy as a way of arranging fiscal policy throughout China’s administrative hierarchy (Jin, Qian et al. 2005).

As China’s irrigation sector adapted to the reform policies, revenue sharing between the village and the irrigation line agencies (irrigation district, township water resources bureau, etc.), and indeed within villages themselves, villages struggled to co-operate in fiscally sustainable ways. The plight of China’s irrigation sector is thus embedded within central and province level efforts to improve rural fiscal policy by devising incentives and institutional reforms to promote the provision of local social and public goods.

The local fiscal self-sufficiency model produced various problems in village irrigation development. Presently, many villages’ fiscal problems begin on the revenue side of the fiscal sustainability equation. Surface water irrigation markets in China, similar to irrigation water markets throughout the world, do not operate according to laissez-faire principles thus the price of water is below market value. Surface irrigation water price is typically set by the township or county price bureau.

A central problem for local irrigation system finances is the artificially low price of irrigation water, and resulting low revenue stream for local irrigation system investment, or operations and maintenance activities.[10] Thus, little capital accumulation for repair or investment to canal systems exists to minimize conveyance losses (Yang, Zhang et al. 2003; Ou, Zachernuk et al. 2004), or invest into water efficiency equipment (Blanke, Rozelle et al. 2007).

Government policy keeps water prices artificially low to ease the burden on farmers and implicitly subsidize agricultural communities (Lohmar, Wang et al. 2003; Shalizi 2006). However, because irrigation water service is generally poor and farmers have little say over the quantity or timing of deliveries, farmers have little incentive to pay more in flat water fees unless they get more, in terms of better timing and reliability of water provision (Ou, Zachernuk et al. 2004). In many cases in China and other developing countries, public agencies' fail to collect fees from farmers at all to support operation and maintenance activities (Easter 1986; Johnson 1990; Gulati, Svendsen et al. 1994; Maskey and Weber 1998). One goal of allowing

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[10] The problem of irrigation water pricing in China is debated widely Yang, H., X. Zhang, et al. (2003). "Water scarcity, pricing mechanism and institutional reform in northern China irrigated agriculture " Agricultural Water Management **61**(2): 143-161, Dinar, A. and J. Mody (2004). "Irrigation water management policies: Allocation and principles and implementation experience." Natural Resources Forum **28**: 112–122, Tsur, Y., T. Roe, et al. (2004). Pricing Irrigation Water Principles and Cases from Developing Countries. Washington, D.C., Resources for the Future.. Three main obstacles face water pricing advocates. First, irrigation water has a larger social imperative than simply watering the earth, including crop production and enhancing rural incomes. After decades of projects aimed at instituting water pricing for irrigation water, advocates of water pricing a the World Bank acknowledge that determining pricing policies for agricultural water use should incorporate the effects of pricing on agricultural productivity and farmer incomes Dinar, A. and J. Mody (2004). "Irrigation water management policies: Allocation and principles and implementation experience." Natural Resources Forum **28**: 112–122.. Second, the infeasibility of measuring water volumetrically at the entry point of the millions of small plot farms in the developing world prohibit volumetric pricing. Third, the lack of an institutional structure that designates clear usufructory rights that would allow a farmer to buy and sell his water allocation makes the institutional provide a further obstacle to market based water pricing.

agricultural water prices to rise, aside from controlling the demand for water via pricing, is to allow communities to establish financially self –sufficient irrigation management systems, where the water fee revenues equal the water system expenditures, and irrigation funds are collected and held separate from other village fees.

A series of irrigation management reforms introduced in the late 1990s aimed to solve many of the coordination and budgeting woes faced by China's village collectives struggling to manage the irrigation systems. Such reform institutions include water user associations (WUAs) and contracting which take the irrigation management function away from the traditional village collective management (Huang, Rozelle et al. 2009). WUAs place operation and maintenance functions of village-level irrigation systems, including fee collection, under the direct control of the water users. WUAs are generally managed through an elected committee comprised of village representatives. Contracting is a system in which the village leaders contract the villages' canals out to an individual, who manages the canal in return for a payment. Recent empirical findings indicate that WUAs and contracting have had little effect on water-use savings in China (Wang et al., 2006). The relationship between irrigation institutions and irrigation performance will be examined more in depth below.

Another problem for local irrigation fiscal policy in China is the lack of separation between the irrigation budget and the general village budget. Irrigation fees typically are submitted into the general village account with fees for other village services, therefore it is unclear if irrigation systems costs exceed revenue, or not. In many cases, including that of collective management in China, irrigation fees go directly into the general village budget and are not set aside to re-invest into the irrigation system. A central tenant of irrigation water management reform, both WUAs and contracting, is keeping irrigation funds completely separate from general village funds in order that revenues funnel back into the system for structural and institutional improvements. Water services experts believe fiscal management reform, with a key stipulation that irrigation finances are separated from the general village fund, may help villages better manage both investment and maintenance activities (World.Bank 2000). However, given the lack of actual change in locus of control under the WUA style of management reform (Caizhen 2008; Huang, Rozelle et al. 2009), whether or not irrigation revenues are held in a separate budget to support irrigation-related expenditures remains unclear.

Another factor affecting local irrigation management is the obligation to fulfill agency and upper-level government policy mandates. Although responsibility for funding local irrigation projects transferred from central to local governments beginning in the early 1980s, central and provincial governments continue to issues mandates for reforms aimed at increasing water use efficiency (Huang, Rozelle et al. 2009), increasing grain production (Yang and Zehnder 2001) and alleviating poverty (Huang, Dawe et al. 2005), thus creating a dynamic push and pull relationship between the village’s fiscal authority and the policy mandates of the overlying bureaucracy.

5.2.2. The irrigation decentralization debate

A recent surge in interest over the junction between fiscal policy and natural resource management has revived a debate on the role of fiscal policy in determining resource management outcomes and is useful for evaluating China's irrigation development. A current trend in natural resource governance involves decentralizing control over fiscal decision making to lower levels of government (e.g. province, city, or village-level) and in some cases the resource users themselves[11], with regard to tariff setting, permitting, allocation plans and infrastructure investment (Ostrom 1992; Munasinghe 1993; Wegelin-Schuringa 2000). According to the decentralization theorists, in locally operated irrigation systems, the role of the upper-level government agencies is to facilitate coordination between smaller jurisdictions and not to exact bureaucratic control over local fiscal policy setting (Uphoff 1991; Fischer and Huber-Lee 2005). Although engineering solutions alone rarely achieve water use savings or increase crop productivity, theoretically, the responsiveness of leaders to local needs and knowledge of local ecological characteristics, along with greater attention to maintenance and operations, improves the provision of service associated with infrastructure project (Faguet 2002). The rationale for localized fiscal management is that local leaders are better informed of local needs, and have greater accountability to local constituents, and will therefore make better decisions on infrastructure provision than people in higher levels of bureaucracy (Martin 1999;

[11] This trend is highlighted in the collective action literature which hypothesizes that resource users will have more to gain than to lose by collectively managing their shared natural resources, also referred to as mutually beneficial collective action. Uphoff, N., M. J. Esman, et al. (1998). Reasons for Success: Learning from Instructive Experiences in Rural Development West Hartford, Conn Kumarian Press.

Jacoby 2000; Foster and Rosenzweig 2001; Lizzeri and Persico 2001; Faguet 2002; Tsai 2007).

From an economic perspective, irrigation development promotes rural and regional economic development as intensification of land-use and diversification of farm crops leads to increased investment and employment (Chapman, Goldberg et al. 2003). In economic terms, the relationship between irrigation and rural economic development is based on irrigation's role as a factor input into agricultural yields (the factor output), where in theory the demand for irrigation infrastructure is derived from demand for crops supported by the irrigation infrastructure.[12] Well-functioning surface water irrigation infrastructure plays three important roles in delivering the raw water resource from the water source to the farm, it: 1) reduces uncertainty for farmers in the timing and quantity of expected water allocation, especially during unpredictable "shock" periods of draught or flood; 2) increases water use efficiency via control of water volume to designated outlets; 3) minimizes loss of water to evapotranspiration and seepage *en route* to farms. As discussed above, altering levers of control over the planning and building of surface water irrigation infrastructure will, in theory impact the effectiveness of the infrastructure. Overall system performance is affected by farmers' maintenance of the structure, using local knowledge to develop the appropriate water use plans and the ability to pay for upkeep of the infrastructure.

[12] Although there is a demand relationship between irrigation (factor input) and crops (factor output), the relationship is not one-to-one.

Indeed the debate continues throughout several bodies of literature in regard to the strengths and weaknesses of decentralization for water resource management. While decentralization proponents argue that integrating local knowledge of the resource and collective action incentives (for local managers and users) makes resource users feel more invested in improving the system performance (Ostrom 1991; World.Bank 2000), recent studies identify a range of problems incurred by locally financed and managed systems. Opponents contend that local governments lack the financial and human resource expertise to provide sufficient public services under decentralization, thus decision making authority should remain in the hands of the central government (Crook and Sverrisson 1999). Others contend that decentralization can increase regional income disparities (Prud'homme 1995). Critics also argue that decentralization leads to more widespread government corruption (in the form of "rent-seeking") (Triesman 2000) and over-exploitation of local resources to benefit local incomes (Brannstrom 2004). While governments experiment with levels of authority over local irrigation institutions, overall, the debate remains open as to which type of governance structure is best for irrigation, and how governance impacts system performance. Using a decentralization framework to analyze irrigation development aids in understanding devolution of responsibilities to village and local control, yet the current literature often overlooks the interplay of fiscal policy with other social and political policy mandates to which villages must adhere.

In fact, the polarized debate over governance form and irrigation neglects the dynamic set of forces at play in China's villages. In particular, an often ignored element of decentralization studies are the levers of bureaucratic control retained by the central government which limit the discretionary authority of the local government (Ribot, Agrawal et al. 2006). Critiques of decentralized governance cite limits on authority as a necessary element of governance to provides checks on local authority on issues of corruption, equality, and regional cooperation (Prud'homme 1995; Faguet 2002). Studies on irrigation governance, however, have yet to integrate developing theories on fiscal policy into empirical work. The majority of work looks at isolated localities in a case study framework, without assessing the inter-relationships of fiscal decisions making within larger jurisdictional units, such as irrigation districts, township, or county.

5.2.3. Summary of the literature on irrigation and decentralization

Although the literature on fiscal decentralization is vast, only recently has decentralization been used to examine natural resource management broadly, and irrigation development in particular. In China, shifts in fiscal policy at the village level have made it unclear to scholars where the actual levers of control over village level irrigation funding and project planning actually lie. The debate over the strengths and weaknesses of decentralization for irrigation investment planning are informed by related debates over forest management and decentralized public goods provision. Recent studies on decentralized natural resource management suggest that local governments are often ill-quipped to manage these complex systems. Related research finds that decentralized systems in fact, often lie somewhere on the central-decentralized structural spectrum as policy mandates from the central government undermine the independent authority of localities to manage their own natural resource systems.

5.3. Research question, hypotheses and analytical approach

5.3.1. Research question

The main research question in this chapter is:

- How do varying levels of village-level fiscal and water resource planning authority impact irrigation development outcomes?

For the impacts of fiscal and planning authority analysis, sample in this chapter is limited to only Henan and Ningxia Provinces (n=55) due to observed variation in the fiscal re-concentration variables in these provinces, and not in Hebei. Figure 2 in chapter 2 depicts the posed relationships between a village's fiscal and water planning authority and three measures of village-level irrigation development outcomes.

5.3.2. Hypotheses

Based upon the theoretical framework described above, the following hypotheses are posed describing the relationship between fiscal policy, irrigation investment, and irrigation system performance.

(H4) *Higher levels of authority (fiscal and planning) retained by the village allow for provision of irrigation services closely tailored to local conditions, and therefore will result in better irrigation and agricultural performance outcomes.*

Sub-hypotheses:

Hypotheses H4-1. Devolved fiscal authority, planning re-concentration and crop water use

H4-1$_1$: *Local revenue and planning decision making decreases water use through higher service levels and more efficient water conveyance and application technologies (increases reliability, quality, and timing).*

H4-1$_0$: *Local revenue and planning decision making does not affect water use levels.*

Hypotheses H4-2. Devolved fiscal authority, planning re-concentration and farmer incomes

H4-2$_1$: *Local authority over irrigation is more responsive to local needs due to higher levels of monitoring and accountability of leaders by/to their constituency, and results in higher village-wide income gains.*

H4-2$_0$: *Local authority over irrigation does not affect incomes.*

Hypotheses H4-3. Devolved fiscal authority, planning re-concentration and agricultural yields

H4-3$_1$: *Local authority over irrigation increases agricultural yields by providing more predictable and timely water supply (decreases uncertainty around key crop input of irrigation water).*

H4-3$_0$: *Local authority over irrigation does not impact agricultural yields.*

5.3.3. Analytical approach

Similar to the determinants study, this assessment of at irrigation development outcomes in northern China will use a quasi-experimental design with three waves of panel data. This study uses comparison groups based on observational data for the analysis of village fiscal policy in three time point, 2001, 2004, and 2008. The research design tests the devolution hypothesis (H4), and is based the observation that marginal retention of revenue (MRR), our treatment condition, is changing within the sample population over time, with over 90% of villages remitting 100% of irrigation fees to the ID by 2008 (see Figure 6 in chapter 3). Observational groups will be classified according to high and low level of *Marginal Retention of Irrigation Revenues* by the village. Additional hypotheses will be tested via nested models to see if other revenue and irrigation planning authority measures influence irrigation system performance outcomes.

The staggered nature of villages' transition to lower levels of investment authority, villages changing from high to low MRR, raises many important issues in the careful structuring of this quasi-experimental design. Due to the unknown establishment of fiscal autonomy levels, observations that would establish baseline population characteristics prior to rural reform (de-collectivization) are not possible. In fact, villages' local fiscal structure transitioned to varying degrees of fiscal autonomy throughout the 10-year survey period. Thus, the study faces two problems in experimental design integrity. First, the two groups of villages may be non-equivalent in their initial characteristics, and thus the changes observed over time may not be attributable to the intervention, but to other omitted factors. Next, the intervention itself may be attributable to existing village characteristics (endogenous characteristics) that made this policy change occur within the village, or contributed to upper-level government's selection of the village for this policy change. In either case, the differences observed between the treatment and comparison groups will be biased due to omitted village characteristics. The variables and measures are described in section 5.5.1 below.

5.4. Assessing impacts of shifting levers of authority on irrigation development

This section uses the *NCIM dataset* as the basis for an analytical framework to assess shifts in levers of fiscal and water planning authority occurring in China during the 10-year study period. The functional division of authority over village irrigation decision making is first described. Next, the fiscal re-concentration and water planning devolution framework is introduced. The last section assesses the implications of the re-concentration and devolution shifts for irrigation development outcomes in northern China.

5.4.1. The framework

Decision making over fiscal policy matters, that is, revenues, expenditures, and related decisions, is in China often separate from water resource planning which manages the timing, flow and allocation of the raw water resource for surface water irrigation. To conceptualize this distinction and apply it to a study of irrigation development, this study draws on terms first applied to a study of fiscal and political structure in rural Africa. In her study on rural power structures in Africa, Boone *et al* use the terms ‘deconcentration’ and ‘devolution’ to refer respectively to the extent of state agency penetration of control in the countryside, and the amount of fiscal autonomy given to local powerbrokers (Boone 1998). Borrowing from Boone’s terminology, this work uses the terms *devolution* and *re-concentration* to describe the development of China’s village-level irrigation fiscal and water allocation structures over the last ten years. Applying these terms to an economics framework, allows one to integrate the behavioral assumptions behind the observed trends of devolution and re-concentration to understand how varying degrees of fiscal authority and bureaucratic resource management explain irrigation development outcomes.

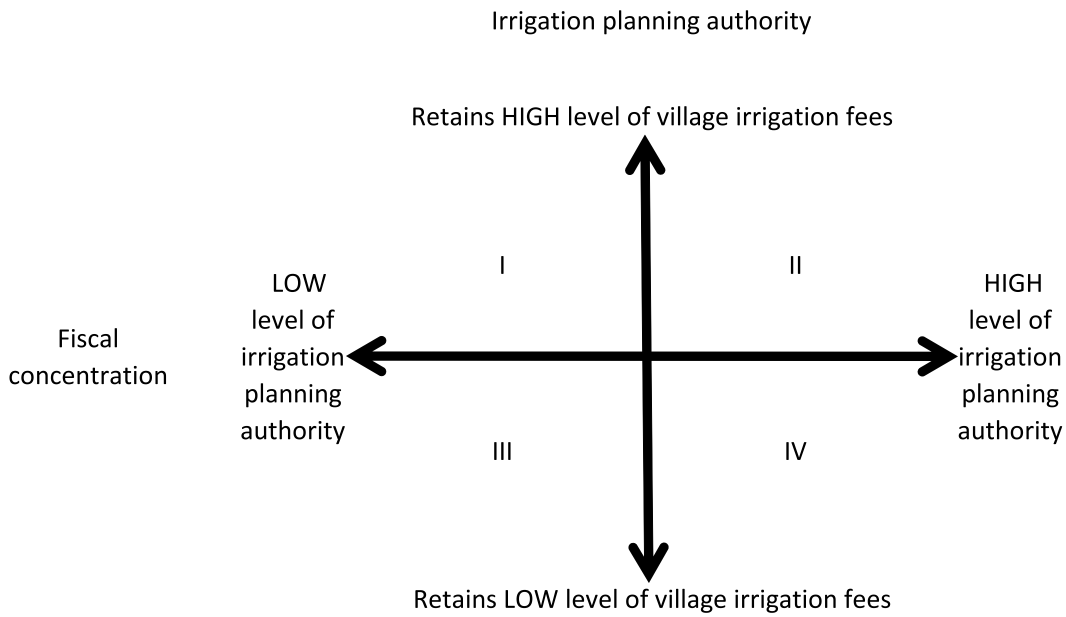
Table 20 Decision making activities in northern China's village irrigation systems

Fiscal policy activities	Resource planning activities	Operational activities
collect irrigation fees	set village allocation plan	control sluice gates
set irrigation fees	coordinate village water deliveries	mediate disputes
settle accounts with water supplier		maintain canals
sign contracts		
make village investments		

Re-concentration is defined as the upper-level government agencies' taking back authority to make irrigation-related fiscal decisions, such as setting irrigation fees, collecting farmer fees, setting irrigation budgets, making capital investments and settling the village irrigation account (see Table 20). Devolution is defined as the further granting of local decision making over water resource planning activities including setting the village allocation plan, coordinating water deliveries amongst farmers and choosing the management institution type.

According to the *NCIM survey data*, levers of authority over irrigation-related decision making have shifted in the last decade. In the late 1990s in China, most village irrigation systems fell under the Type I or II classification (as seen in Figure 10 typology chart of degrees of fiscal and water planning authority), characterized by high degrees of local autonomy over fiscal decision making and varying degrees of water resource planning authority. By 2008, the irrigation management functions changed as more villages migrated to Type III and IV authority regimes.

Figure 10 Degrees of authority in village irrigation fiscal and water planning



Based on this study's analysis of the fiscal related reforms occurring during this time period (see chapter 3 *Timeline of economic and political shifts impacting irrigation development*), a number of rural development policies altered the levers of control over irrigation development and planning in villages. As illustrated by the shifts of villages into the upper-level government fiscal concentration category (Types III and IV), irrigation districts and other upper-level government agencies altered revenue sharing agreements and required villages to remit 95% - 100% of farmer fees to the upper-level agency (see figure 6 in chapter 3) . A shift from highly devolved fiscal policy to a re-concentration of fiscal authority under the bureaucratic control of upper-level irrigation agencies changes villages' fiscal and irrigation management landscape, and is the material which this analysis will further explore.

5.4.2. Implications of re-concentration and devolution patterns

One important implication of decreased relative and absolute amounts of village-level irrigation revenue on the investment behavior of villages in regards to expending capital on irrigation infrastructure development. In fact, although the share of irrigation fees remitted to the upper-level agency water bureau increased, the share of village-level infrastructure spending by villages remained relatively constant whilst the transition to lower MRR occurred.

The gradual centralizing of fiscal authority into the hands of water and irrigation agency bureaucracies has several implications. First, concurrent to villages' share of irrigation fees retained by the village (MRR) decreasing; the promulgation of WUAs began with the aim of promoting transparency related to water quantities, fees and decision making processes. Irrigation managers, from WUA leaders to contractors, assumed greater responsibility for collecting fees from farmers, from 20% of villages where a local irrigation manager collected fees in 2001, to 46% of villages where a local irrigation manager collected fees in 2008 (see Table 9 in chapter 3). The increased responsibility of collecting fees is at odds with promoting local fiscal self-sustainability (higher marginal retention of revenue), which is to incentivize managers to regularly collect fees by allowing them control over budgeting of the collected revenue. Although an overall trend of re-concentration of fiscal authority occurred by 2008, division of fiscal responsibilities varies between villages, with some villages retaining higher levels of fiscal independence, and others under tight control of ID / county administration.

A second implication of fiscal re-concentration is that decreases in relative and absolute amounts of village irrigation funds retained undermine local-level fiscal decision making authority. Examples of local-level decision making taken out of the hands of local managers include village-level discretionary spending on operations, maintenance and capital investments. Such a shift from devolved authority over irrigation and resource management to re-concentrated fiscal authority in the hands of upper-level government bureaucracy aims to solve many of the ills associated with the “elite capture” problem within China’s villages (Oi 1992). The ‘elite capture’ problem occurs when a large portion of the resources devoted to irrigation development fall into the hands of powerful groups dominating communities (Baland and Platteau 2004), thus undermining the usefulness of devolved decision making to be more responsive to local needs and providing more targeted and effective public goods and investments.

Where a return to bureaucratized allocation system for making capital investments may deflect risks involved with elite capture, it incurs new risks associated with cronyism within the bureaucracy, politicized funding decisions not reflecting the needs of communities and loss of accountability for villagers and leaders for the upkeep and maintenance of capital projects. An important aspect of the re-concentration of central authority over irrigation development is the return to bygone days of rural China (pre-1979 reform) where the collective action potential of villages and farmers to cooperate in decision making and fund raising was undermined by attitude of passive “waiting in line” for government fund and project allocation. The risks of reducing village participation in their own irrigation development efforts includes both the risks to the overall provision of irrigation development activities including institutional development, irrigation planning, leadership training, capital investments and commitment to operations and infrastructure maintenance.

More bureaucratized water planning decision making has been found to remove decision making from the knowledge of the actual resource and result in misallocation of water and neglect of irrigation systems (Uphoff 1991). In theory de-concentrated operational decision making improves service via: localized knowledge of needs, localized knowledge of water and land resource conditions, and increased accountability of local operators to local people. However bureaucratized decision making can aid in facilitating cooperation with other regional users; is a mechanism to limit local authority and natural resource exploitation (Ribot, Agrawal et al. 2006). Shifts in water resource planning for China's village irrigation sector remain un-examined, this study aims to fill this gap and further assess the irrigation outcomes related to particular levels of water planning authority found in the northern China sample.

5.4.3. Summary of variation in local fiscal authority and irrigation development outcomes

This section considers three indicators of irrigation development, spanning both social and environmental realms. To assess irrigation development performance, three positive potential outcomes of irrigation development include: increases in agricultural yields, poverty alleviation and water conservation. More in depth description of shifts in local fiscal authority and irrigation development outcomes is found in chapter 3.

5.4.3.1. Outcome 1: Water conservation

Decreasing water use on crops is the first irrigation development outcome. Despite the Chinese government's call to create a "water saving society" (*jieshui shihui*), especially in the dry north China plain, the average village in the *NCIM* sample uses more irrigation water to grow crops in 2008 than in 2001, increasing from 381 cubic meters per hectare per growing season in 2001 to 501 cubic meters per hectare per season in 2008. About half of the villages in the sample rely solely on surface water for irrigation, while the remaining 50% use conjunctive use of groundwater and surface water sources. One explanation for the rise in crop water use may be the improvement of regional and local irrigation infrastructure in northern China. Surface water investment per hectare, including upper-level and local-level government funds, averages around 32 Yuan per hectare from 1998 to 2001 and 31.21 Yuan per hectare between 2005 and 2007. Investment per hectare drops to 10.45 Yuan per hectare between 2002 and 2004. With such investment, gross infrastructure stock has steadily risen with the average village having 168,000 Yuan (USD 24,597) worth of irrigation capital assets by 2008[13]. Much of the infrastructure development has focused on minimizing conveyance losses, through canal lining projects, and improving distribution methods via pumps and diesel pump engines.

[13] Calculated using straight line depreciation schedule.

Such increased efficiency and ability to procure more water, may explain how villages are able to use more water per hectare, despite the drought conditions.

5.4.3.2. <u>Outcome 2: Wheat crop yields</u>

The crop used to assess agricultural and water use outcomes for this analysis is winter wheat, making up 62% of sown crop area in north east China (FAO 2008), winter wheat is planted in September - October and harvested in April-may (FAO 2008). 20.4 percent of China's winter wheat is produced in Henan. Spring wheat is also planted in Ningxia, whose spring wheat yield comprises 6.3% of China's spring wheat production. Spring wheat has a shorter growing season, planted in April-May and harvested around August. Wheat is planted in the dry season and relies on irrigation for much of the growing season and is susceptible to droughts and irrigation shortages which have occurred frequently over the past ten years, making for unfavorable growing conditions during critical stages of the wheat crop's growing process.

A typical village in the sample in northern China had relatively stable wheat production between 2001 and 2008, averaging about 2,600 kilograms of winter wheat per surface water irrigated hectare per year. According to Food and Agriculture Division of the United Nations, average wheat production per hectare for China in 2000 was 3,729 kilograms per hectare, up from an annual average yield of 1,891 kilograms per hectare in 1981. Allowing for slight differences in calculation methods, average production in northern China's arid and semi-arid zones is lower than China as a whole. In fact, the sample yields are closer to averages in other arid and semi-arid zones such as India (2,777 kg / ha) or Tajikistan (1,101 kg / ha) (FAO 2008).

5.4.3.3. **Farmer income**

Farmer income is the next irrigation development outcome. Economic conditions in China's rural regions are poor. According to the 2000 China National Rural Survey conducted by CCAP, the average per capita income (farm and non-farm) is US $290 per year (2,257 Yuan), and the average land-holding per capita is 0.148 hectares (2.47 acres) (Huang, Rozelle et al. 2006). Within the *NCIM* sample population, in 2001 per capita income was slightly less than the national average, at US $248.46 annual income per capita (1,697 Yuan), while this study does not measure land holdings per se, average sown area per capita is around 1.6 hectares per capita, indicating larger farm plots than the national average.

Where agricultural yields in northern China at the turn of the 21st century have been stable, rural incomes have risen steadily. Per capita income in a typical sample village rose by almost twofold between 2001 and 2008, from 1,697 Yuan (USD 249) annual income per capita, to 3,229 Yuan (USD 473). Increasing incomes can be attributed to many factors. From remittances sent from migrant workers (Khan and Riskin 2008) to development of rural enterprises (Oi 1999) to advances in rural agricultural development in the form of irrigation infrastructure (Huang, Dawe et al. 2005), and other farming technologies. While the rise of rural incomes is remarkable, it must be noted that farmers in these villages remain poor, averaging net income of around $1.30 per day, per person.

5.4.3.4. **Assessing Fiscal policy and irrigation development outcomes**

Average agricultural yields in the sample villages fluctuate between all periods over the duration of the study. In 2008, villages with higher revenue authority have lower agricultural yields than villages without revenue authority (see Table 21). The fiscal and irrigation planning measures indicate no clear pattern related to how fiscal authority relates to agricultural yields outcomes.

Table 21 Local fiscal and planning authority and irrigation development outcomes

Fiscal Authority & Productivity in villages in northern China (n=55)
Average seasonal water use, wheat productivity

	Irrigation Water Use* (m^3 / ha for wheat crop)			Agricultural Productivity* (kg wheat / ha)			Farmer Income (2000 RMB / capita)		
	2001	2004	2008	2001	2004	2008	2001	2004	2008
Revenue Authority									
Marginal Retention of Revenue is > 17%									
Yes	407	412	513	2,351	2,443	2,869	1,726	2,211	2,603
No	371	307	500	2,658	2,578	2,678	1,686	1,665	3,276
Invests local funds in irrigation infrastructure?									
Yes	433	399	594	2,516	2,691	2,558	1,997	1,950	3,653
No	345	298	384	2,608	2,430	2,850	1,488	1,748	2,723
Village responsibility to collect water fees?									
Yes	471	329	724	2,576	2,567	2,394	1,836	1,995	3,517
No	347	354	293	2,523	2,551	2,941	1,637	1,796	2,969
Decides water fee within village?									
Yes	515	544	177	2,284	2,558	3,012	2,173	2,117	1,486
No	352	300	520	2,633	2,533	2,674	1,594	1,594	3,325
Water management authority									
Decides water allocation within village?									
Yes	477	-	231	2,344	-	3,000	1,988	-	1,476
No	365	365	365	2,608	2,537	2,686	1,649	1,831	3,260
Coordinates irrigation delivery within village?									
Yes	497	237	723	2,499	2,614	2,559	1,914	1,592	3,239
No	349	380	407	2,589	2,538	2,748	1,637	1,939	3,224

* surface water use only
**light shading is the higher value within the year & fiscal category, dark shading is the lower value

Source: CCAP: *Northern China Irrigation Manangement Survey*

In villages where farmers invest local funds, and where responsibility for collecting water fees remains in the village, farmers have higher per capita incomes throughout the study period (see Table 21). Within the descriptive statistics, irrigation planning authority, such as *who decides water fees*, did not reveal any clear or consistent pattern in differences between villages with different planning characteristics.

For irrigation water use, within the north China sample, villages investing local funds into irrigation infrastructure, use more water than villages that do not (594 m^3 / ha with local investment, 384 m^3 / ha without local investment – see Table 13), however the direction of causation is not clear. When considering the added element of level of fiscal authority, measured as a village's marginal retention of irrigation revenue (MRR) however, it is interesting to note that villages with high MRR consistently use more water than villages with lower MRR (also referred to in Table 15), such villages are often the same ones investing village funds into local irrigation infrastructure, presumably with the purpose of procuring greater quantities of water. Overall, according to descriptive statistics, villages retaining higher levels of irrigation fee revenue have higher water use, slightly lower agricultural yields and higher farmer incomes.

5.4.4. Summary

Descriptive assessment of variation in levels of local fiscal authority and irrigation development outcomes in northern China reveals large shifts in management regimes occurring in the northern China countryside. On one hand, authority over irrigation funds and project planning is being re-concentrated back to the direct control and supervision of regional irrigation agencies. On the other hand, water resource planning is increasingly under the control and supervision of the water users and contractors. In both cases, the village collective leadership is playing less and less of a role in irrigation management.

5.5. Multivariate Analysis: Impacts of fiscal and water planning authority on village irrigation development

Although the descriptive statistics reveal trends across time and space within the north China study area, it is not entirely clear how specific aspects of villages' irrigation fiscal and water planning structure impact village irrigation performance, related to water use rates, agricultural yields and farmer incomes. To more carefully evaluate how variation in fiscal and resource planning structure affects irrigation development outcomes, this study employs multivariate analysis. This section contains several parts. First, variables used for analysis are defined and described. Next, the research design and analytical approach is described. The next section employs multivariate analysis to analyze the relationship between irrigation fiscal and resource planning authority and irrigation performance in villages in northern China over the years 2001 to 2008. The fourth section uses instrumental variables analysis to address the "within system" effects, or endogeneity, of the treatment variable on the statistical outcomes. Finally, results are reported and explained.

5.5.1. Variables and Measures

Based on the literature and policy documents for China's irrigation development goals, three outcomes are used to evaluate the village-level irrigation system performance.

5.5.1.1. Outcome (dependent) variables

First, to measure changes in agricultural water use under various fiscal management schemes, this study uses a measure of each village's seasonal water use for one crop common to all village in northern China, wheat. Based on data from 2001, 2004, and 2008, a rate for surface water use per wheat crop per hectare, per irrigation application each year in each village is systematically calculated (see Appendix C for crop water use and crop yield calculation procedures). The *crop water use rate* for wheat is based on number of seasons and amount of water applied to the wheat crops in each village. Wheat crop water use is meant to capture changes in crop water use between years, and between villages due to changes in water application and water allocation practices.

The next outcome measure is *crop yields* is based on village leaders' and surface water managers' accounts of annual wheat production in the village, volume (kilograms) of wheat produced per hectare of irrigated land is calculated. The third outcome variable is *net annual per capita farmer income* for each village, as reported by the village leader based upon his records for the previous year. This measure is used to measure changes in farmer income and evaluate the goal of poverty alleviation. All incomes are normalized to real Yuan in the year 2000.

5.5.1.2. Explanatory Variables

Due to the diverse nature of fiscal policy for irrigation management, this study avoids uni-dimensionally measuring fiscal decentralization of village irrigation, and accomplishes this by following the tradition of other fiscal studies in using MRR as a proxy for the level of incentive faced by village irrigation leaders to generate and collect irrigation revenue, in addition to other fiscal policy decisions described below.

Marginal Retention Rate

One way to measure the degree of fiscal authority of villages is by looking at the share of irrigation revenue the village keeps and the share remitted to the irrigation district, referred to as the MRR. In theory MRR increases discretionary spending power of local government (Oksenberg and Tong 1991; Oi 1992; Lin and

Liu 2000; Fan, Zhang et al. 2002; Jin, Qian et al. 2005) and incentivizes revenue generation (such as collecting fees; adding ad hoc fees).

Several studies use the marginal retention of revenue to measure the degree of fiscal autonomy, or fiscal incentives, faced by provincial governments. MRR is used both as a fiscal policy measure utilized by central governments to grant local fiscal autonomy (Oksenberg and Tong 1991), as well as an empirical measure of fiscal decentralization defined as the share of locally collected budgetary revenue the local government is allowed to keep (Lin and Liu 2000; Akai and Sakata 2002). Lin and Liu go so far as to measure the degree of fiscal decentralization as the province's MRR.

MRR is calculated as the share of surface water irrigation fees retained by the village irrigation leadership, as a portion of total fees collected. Several scenarios may determine a village's MRR. It may be the case that the ID charges a determined fee, and the irrigation manager simply sets local fees above that in order to secure village funds for the irrigation system. Alternatively, the local irrigation administration may designate a fee sharing arrangement, as common in other county-village fiscal arrangements (Oksenberg and Tong 1991), where no matter what absolute amount is collected, a pre-determined share of the proceeds will be retained by the village, and the remainder submitted to the ID. Although it is unclear who mandates the portion of fees retained by the village irrigation leadership, variation in the levels of MRR within villages and between villages is observed, and it is hypothesized that higher levels of funds retained by the village allows for provision of goods and services closely tailored to the needs of villagers, and therefore will result in better irrigation and agricultural system performance. Lastly, variables high marginal retention rate and investment per hectare are interacted to assess if investment project performance varies when a village retains more funds for discretionary spending.

Other fiscal and water resource authority variables

In addition to MRR, the analysis includes a set of additional fiscal decision making dummy variables, indicating whether or not villages have authority over: 1) deciding irrigation fee levels, 2) collecting fees from farmers, 3) making village-level irrigation investments, and 4) signing irrigation –related contracts. To estimate the impact of water resource management on village outcomes, the analysis uses two dummy variables related to authority over water resource management: 1) whether or not village irrigation leaders decide village water allocation plan; and 2) whether or not village irrigation leaders coordinate delivery of water for village farms. The analysis will assess if these groups of variables impact village crop water use, crop yields and farmer income levels.

Control variables

Other control variables included in the models are irrigation management type, a few measures of village wealth including village enterprise income, gross surface water irrigation stock though the previous time period, whether or not farmers in the village invest private funds toward irrigation infrastructure and total surface water investment per hectare in the current time period. The analysis also controls for whether or not the village relies exclusively on surface water, instead of conjunctive use of surface and ground water sources, the number of laborers in the village, and sown area per capita in the village to measure if economies of scale are occurring related to production, water use and income. For the agricultural yields model, a dummy variable for soil quality is added indicating yes if the village has high soil quality. The hypotheses for variables with significant effects will be discussed in the results section.

5.5.2. Models and methods

Bias due to lack of establishment of temporality is a gap in current research on the relationship between local fiscal policy and development outcomes. Cross-sectional designs cannot establish temporal precedence, making them particularly vulnerable to invalid inferences due to unobserved characteristics of the village that may explain assignment into the treatment (High MRR) category (strong grassroots fiscal leadership may be a result of a village's strong socio-economic and/or natural endowments) occurring concurrently with observed outcomes. Positive relationships between the local irrigation development and fiscal policy can be attributed to (1) the community's natural and social endowments, (2) the institutional setting of the village and local government agencies, or (3) both. Indeed, potential endogeneity is regarded as the primary limitation in studies of how fiscal policy impacts development (Lin and Liu 2000; Jin, Qian et al. 2005).

This study uses multiple strategies to control for potential endogeneity including use of several models for comparison of the robustness of the specified models (see Table 22). Most fundamentally, this study on the impact of irrigation fiscal policy on local irrigation development outcomes uses three waves of panel data through which changes in irrigation and development outcomes can be examined in relation to changes in local fiscal structure over time. In order to make plausible causal inferences on the impact of fiscal autonomy on irrigation development outcomes, given the non-random assignment of the explanatory factors to villages, careful attention is given to experimental design in the econometric models. First, the careful use of dummy variables in each multivariate model allows me to separately account for within comparison group changes (pre-treatment to post-treatment changes) (see Equations 4 and 5) and within both groups changes (post-treatment vs. post-control changes).

$$\beta = (\overline{Y}_{\text{treat, post}} - \overline{Y}_{\text{treat, pre}}) - (\overline{Y}_{\text{control,post}} - \overline{Y}_{\text{control,pre}}) \tag{4}$$

$$Y_{igt} = \alpha + \delta_2 \,\text{Treat}_g + \delta_1 \,\text{Post}_t + \beta \,Post_t * \text{Treat}_g + \varepsilon_{igt}, \text{where } \varepsilon_{igt} = v_{igt} \tag{5}$$

Table 22 Impacts: Models, Variables, and Analytical Tools

unit of analysis: village			
Model	**Dependent Variable (s)**	**Key Independent Variables**	**Analytical Tool**
Fiscal Devolution Model I	▪crop water use ▪crop productivity ▪farmer per capita income	▪Marginal revenue retention rate	Difference-in-Difference
Fiscal Devolution Model II	▪crop water use ▪crop productivity ▪farmer per capita income	▪Marginal revenue retention rate	2 Stage Least Squared
Fiscal Devolution Model III	▪crop water use ▪crop productivity ▪farmer per capita income	Revenue Authority Measures: ▪village collects fees ▪village sets fees ▪village invests funds into irrigation	Difference-in-Difference: Nested Models
Water Resource Planning Concentration Model	▪crop water use ▪crop productivity ▪farmer per capita income	Water Resource Planning Authority Measures: ▪village sets water allocation plan ▪village coordinates water deliveries	Difference-in-Difference: Nested Models
control variables: irrigation management type, village enterprise income, gross surface water irrigation stock through the previous time period, and net per capita income. To control for other land resources, I include variables for wheat productivity, and system size (meter of canal length). exclusive use of surface water, the number of laborers in the village, and sown area per capita in the village.			

This study utilizes a variation of the difference in difference (DD) model as the control model with treatment interactions, understanding that DD is essentially a model that allows me to test for whether treatment causes "structural change" in the underlying relationships. This estimator is also called a "within" estimator, since it only "uses" the variation in treatment status within each cross-sectional group. By contrast, the between estimator only uses variation between cross sections of data.

The estimators above are examples of fixed effect estimators that hold constant time-constant village-level characteristics in order to isolate the effect of time invariant characteristics of interest from the treatment variable parameters. Another measure to increase the validity of the estimators is the use of instrumental variables two –stage least squares (IV 2SLS) techniques to correct for assignment of villages to the treatment group, based upon unobserved time varying factors.

Econometric modeling for addressing endogeneity simultaneously models predictors of the exposure and the outcome of interest. In another approach, instrumental variables analysis controls for endogeneity through the application of a valid instrument. An instrument is a variable that (i) has a causal effect on the exposure, (ii) affects the outcome only through the exposure, and (iii) does not share common causes with the outcome (Hernan and Robins 2006). Instrumental variables can control for endogeneity due to unobserved characteristics, but the variables' effectiveness depends on the validity of the instrument. Also, the instrumental variable estimate does not necessarily reflect the average effect in the whole population, the target population of interest for exposures, such as village fiscal structure.

5.5.2.1. Methodology for analysis of impacts of fiscal structure on local irrigation development

To assess the impacts of fiscal structure on development outcomes, three dependent variables are used: 1) annual wheat crop water use per hectare per village;

2) annual wheat volume per hectare per village; and 3) annual per capita farmer income (from farm sources) per village. All three dependent variables are continuous[14], and recorded for three time periods (1998-2001, 2002-2004, and 2005-2007). The main explanatory variable, marginal retention rate of irrigation fees is measured as a dichotomous variable where MRR equal to or greater than 17% (the mean) indicates high MRR and all values less than 17% are classified as low MRR. Treating MRR as a dummy variable allows use of MRR as the treatment explanatory variable.

Based on the previous discussion, the link between magnitude of irrigation development outcomes and fiscal policy can be represented by the following equation:

$$(ID_{it} - ID_i^*) = \beta_1 (MR_{it} - MR_i^*) + \beta_2 (FP_{it} - FP_i^*) + \sum \beta_3 \ (V_{itk} - V_{ik}^*) + (u_i + e_{it}) \quad (6)$$

In this model, I measure the average treatment effect is measured as the difference between the treatment outcome under low MRR minus the average outcome prior to changing fiscal authority structure. β_1 estimates the development outcome for village *i* after the change in MRR. In the equation above IDrepresent each of three irrigation development outcomes, crop water use rate, crop yields and farmer incomes. MR is a village's marginal retention rate of irrigation revenue. FP is a vector of fiscal and resource authority measures and V represents a vector of other predictors of irrigation development. In this model, *t*=1, 2, 3 and *i*=village. For agricultural yields, a dummy variable for soil quality is added indicating yes of the

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[14] I conduct multiple tests for specification of functional forms on these three dependent variables. The BoxCox test provides an ambiguous result, where a p-value of 0.000 on the null that λ=0 (fail to reject), and a p-value of 0.001 on the null that λ=0 (fail to reject). I run the Wooldridge Psuedo R^2, test for a logged versus unlogged variable. The result rho=.067, R^2, and the R^2, from the unlogged model = 0.139, unlogged form is preferred.

village has high soil quality. The error term for the fixed effect models is decomposed into two parts, u_i is the unobserved time-invariant village-level heterogeneity for the fixed effects models, and e_{it} is the idiosyncratic error term assumed is uncorrelated with any of the explanatory variables. Village-specific error ($u_i$in fixed effects models) subtracts out and therefore will not bias model estimates[15].

5.5.2.2. Instrumental Variables

Although fixed effects model's calculation of deviations from the mean reveals changes in development outcomes while differencing out time invariant village-level characteristics, there still exists the possibility that time varying changes within the village could bias estimates of the impact of fiscal structure on irrigation development. In order to control for bias due to time variant and invariant, observed and unobserved characteristics instrumental variables are used to estimate a Two Stage Least Squares Model (2SLS) to correct for bias due to "within village" time varying characteristics. In the absence of homogeneous effects, the 2SLS estimate will differ from average effects estimated using fixed effects, even if unobserved characteristics did not bias the associations. A 2SLS model is specified:

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[15] Hausman Specification Tests are conducted for each model to see if a random effects or fixed effect model is preferred. For crop water use and farmer income, the failure to reject the null (chi^2=24.62, pr>chi^2=0.0009; chi^2=15.07, pr>chi^2=0.0351, for water use and farmer income respectively), indicate the fixed effect model is preferred on the grounds of being unbiased and consistency. For crop productivity, the test statistic chi^2=10.16; pr>chi^2=0.1797 rejects the null indicating the random effects model is preferred on efficiency grounds. For the random effects model, a version of the generalized least squares model (GLS), In order for random effects coefficients to be valid, the model must be strictly homoskedastic and show no first order autocorrelation. White test results for crop productivity indicate no indication of heteroskesdasticity (p value =.368 fails to reject the null of homoskedasticity in the model) and no autocorrelation (H_0: no first order autocorrelation $F(1, 49) = .032$; Prob > F =0.8593).

$$MR = \propto_0 + \propto_1 Z_k + \propto_k (other\ predictors) + \epsilon_{it} \quad (7)$$

$$ID = \beta_0 + \beta_1 MR^* + \beta_k (other\ predictors) + \epsilon_{it} \quad (8)$$

Where Z_k are instrumental variables to over-identify for the instrumented variable, MR^*. Instrumental variables for this model are: 1) education of party secretary, 2) canal system size, 3) policy decision for management reform made by (within) village and 4) distance from urban center.

5.5.3. Results

This section reports the results of three sets of multivariate models, to evaluate the impact of revenue authority and water resource planning authority on 1) crop water use, 2) crop yields and 3) farmer incomes. In model Set A (crop water use) and Set C (farmer income), fixed effects models are specified and sample average treatment effects reported (see Equation 3), where model parameters represent deviations from the within village means. These models evaluate how changes in marginal retention of revenue within villages altered patterns of irrigation development outcomes of interest. The models also assess how other aspects of irrigation governance including other measures of fiscal policy and irrigation planning authority impact irrigation development. In Set B, crop yields models, random effects models are specified and again, sample average treatment effects reported.

External validity for each of the three models would require a sufficiently high power calculation where the sample would indeed represent the northern China population of villages, however external validity in this case is limited by the sample size of 56 villages, in a region containing approximately over 2,500 villages (China

Statistical Bureau 2008). The internal validity of the estimates is strong. The panel covers three waves of data over a ten-year time period so that the temporal order of precedence is clearly mapped over time, establishing temporal order of cause before effect. In addition, the analysis employs instrumental variables to address concerns of endogeneity wherein the treatment (MRR) is correlated with observed or unobserved factors (‘confounders’). For the IV results, local average treatment effects are reported related to a village’s decline in revenue authority over irrigation funds.

5.5.3.1. Crop water use and fiscal authority models

The crop water use model (Table 23, Set A) performs well, with the specified variables explaining 44% (R^2=0.44) of observed within village variation in village crop water use over the three wave panel. Several of the control variables are significant and have signs in the hypothesized direction. For example, village enterprise income has a small but significant impact on rates of village crop water use, where for each 100 Yuan in additional income, the rate of crop water use declines by 2 cubic meters per hectare, holding all factors constant (Set A, Column V, Row 17). This suggests several possibilities, either competition for fixed allocations of water in the village creates more efficient agricultural water use, or perhaps that surface water infrastructure in place for the village enterprise provides efficient means of water distribution for farm level distribution as well. Investment into surface water irrigation infrastructure also has a positive effect on water conservation. For each 100 Yuan per hectare of investment, a village uses 116 cubic meters per hectare less than the village average, holding all factors constant (Set A, Colum V, Row 9). Investment rate in the current time period had a significant and positive effect on water conservation, while gross stock in investment, a lagged variables representing investment through the previous time period, was of small magnitude and not statistically significant. Such a difference between new versus old infrastructure stock suggests that the effectiveness of infrastructure in saving water can be explained by a number of factors including a relatively short useful life of surface water irrigation infrastructure in the villages, or changes in irrigation infrastructure projects aimed at promoting water conservation that became more widespread in the early 2000s.

Table 23 Set A: Impacts of fiscal & planning authority on crop water use: Village-level fixed effects

Dependent variable: seasonal wheat crop water use (m^3 / ha / season)

		Fixed Effects					IV	
		I	II	III	IV	V	VI	VII
		β	β	β	β	β	β	β
1	High MRR * Investment Rate		-0.345	-0.071	-0.422	-0.161	-0.822	-0.651
			(0.950)	(1.004)	(0.965)	(1.03)	(0.988)	(1.049)
2	High level of Marginal Retention of Irrigation Revenue (Dummy=1 if above average MRR)		-112.93	-124.887	-108.97	-121.41	-98.536	-98.110
			(50.956)**	(55.109)**	(52.049)**	(56.106)**	(53.886)*	(58.739)*
3	Village invests local funds to irrigation capital projects (Dummy=1 if yes)			9.863		7.764		-17.085
				(51.826)		(52.937)		(56.908)
4	Irrigation water price set by village (Dummy=1 if yes)			-59.031		-56.122		-54.277
				(72.793)		(74.786)		(77.583)
5	Irrigation contracts signed by village (Dummy=1 if yes)			91.343		90.2566		112.20
				(58.898)		(60.092)		(62.71)*
6	Irrigation fees collected by village (Dummy=1 if yes)			11.120		22.020		-7.733
				(53.872)		(60.228)		(65.559)
7	Allocation decided within village (Dummy=1 if yes)				-32.093	-21.734		-88.253
					(85.038)	(89.7306)		(98.756)
8	Delivery coordinated within village (Dummy=1 if yes)				-27.173	-25.121		29.656
					(47.303)	(54.0122)		(61.412)
9	Surface water investment per hectare (RMB / ha, for time period)	-1.072	-1.163	-1.189	-1.140	-1.166	-1.207	-1.256
		(0.338)***	(0.339)***	(0.353)***	(0.345)***	(0.359)***	(0.358)***	(0.381)***
10	Sown area per capita (ha / capita)	-2.005	-1.859	-7.859	-3.392	-9.055	4.320	-0.540
		(16.53)	(16.114)	(17.170)	(16.424)	(17.493)	(16.37)	(18.345)
11	Water user association (Dummy=1 if uses a wua)	47.272	40.300	20.994	64.126	34.801	-4.403	-16.970
		(58.787)	(57.806)	(69.497)	(68.494)	(75.143)	(67.656)	(88.506)
12	Contract (Dummy=1 if uses contracting)	66.395	85.370	64.450	100.134	75.414	71.667	40.370
		(49.371)	(49.6217)*	(53.019)	(54.700)*	(57.440)	(51.55)	(60.465)
13	Number of laborers in village	0.110	0.091	0.0850	0.0923	0.087	0.0748	0.064
		(0.068)	(0.067)	(0.071)	(0.068)	(0.0733)	(0.0697)	(0.077)
14	Drought (Dummy=1 if drought reported during time period)	-43.315	-17.812	-17.982	-19.576	-20.261	-27.014	-44.192
		(47.019)	(46.876)	(48.931)	(47.58)	(49.886)	(48.000)	(52.267)
15	Gross surface water irrigation stock (in 1,000 RMB, through previous time period)*	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		(0.000)*	(0.000)	(0.000)	(0.000)	(0.000)	(0.0001)	(0.000)
16	Only uses surface water for irrigation (Dummy=1 if yes)	80.969	100.863	65.087	104.476	70.723	177.353	165.336
		(64.995)	(64.867)	(73.483)	(65.953)	(75.049)	(79.256)**	(91.591)*
17	Village enterprise annual income (in real 2000 RMB)	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001
		(0.001)**	(0.001)**	(0.001)	(0.001)**	(0.001)*	(0.001)**	(0.001)
18	Private investment into irrigation infrastructure present in village (Dummy=1 if yes)	76.184	66.242	60.322	62.431	58.906	98.092	111.536
		(43.695)*	(42.873)	(61.245)	(43.708)	(63.335)	(44.753)**	(67.023)*
19	2001	-42.358	-38.182	-43.438	-28.052	-33.889	-36.316	-22.815
		(51.676)	(50.79)	(53.859)	(54.025)	(57.800)	(54.891)	(63.378)
20	2004	-176.11	-163.483	-155.59	-163.491	-155.553	-163.880	-154.823
		(42.51)***	(41.703)***	(43.22)***	(42.494)***	(44.378)***	(45.628)***	(49.618)***
21	Constant	323.75	346.297	374.33	342.197	368.80	306.906	331.010
		(121.79)***	(120.75)***	(126.23)***	(122.09)***	(128.736)***	(128.405)**	(137.50)**
22	R^2	0.370	0.410	0.430	0.421	0.441	0.447	0.475
23	observations	165	165	165	165	165	165	165
24	F-Test for joint significance of MRR variables		3.49**	3.01**	3.30**	2.87**	6.96**	4.82*
25	F-Test for joint significance of Fiscal Authority variables			0.69		0.28		3.91
26	F-Test for joint significance of Planning Authority variables				0.23	0.88		1.09

In evaluating the impact of MRR, a proxy for the level of central versus local control over fiscal authority related to irrigation, on crop water use, several interesting results emerge. First, the variable *high level of MRR* increases the explanatory power of the models as seen in the higher goodness of fit between Set A, Columns I and II, where R^2 increases from 0.370 to 0.400. Next, the within parameters of *high level of MRR* are consistently significant and of high magnitude. A village retaining a high share of its irrigation revenue uses 121.41 cubic meters per hectare less than average usage during periods when a larger share of revenues are submitted to the upper-level irrigation agency, holding all other factors constant (Column 5, Row 2). When *high level of MRR* and *investment rate* are interacted to assess if investments made within the village during the time when villages retain higher levels of revenue and spending discretion impact crop water use, the direction of the coefficient is as anticipated, but it is not a significant predictor of village-level crop water savings. The other revenue authority policy variables jointly explain a significant amount of variation in within village crop water use rate, according to an F-Test of multiple hypotheses (F = 2.87, $\alpha \leq 0.05$; Column V, Row 24).

Due the prevalence of unobserved "endogenous" variables that threaten statistical validity within public investment and yields models (Aschauer 1989), the analysis utilizes instrumental variables (IV) 2SLS models to address the possibility of endogeneity in the treatment variable (*high level of MRR*). IV models are based on Equations 4 and 5, and results for crop water use are reported in Columns VI and VII[16]. The IV models strengthen the explanatory power of the model and also produce several more statistically significant explanatory variables. In the IV models, *uses surface water only*, and one fiscal policy variable, *village has authority to sign irrigation contracts,* are associated with villages' crop water use rate. When a village

[16] Diagnostics for validity and strength of IV instruments can be found in Appendix B

leader or irrigation manager has authority to sign contracts, the village water use rate is 112.20 m^3 per hectare higher than the average usage when a village does not have such authority, holding all other factors constant (Column VII, Row 5). Such an outcome may be a result of local irrigation managers having greater authority to contract out canals and access to village water supplies, and utilize more water in a quasi-privatized water market form. Additionally, results indicate that within the sample villages, where farmers invest private funds into surface water irrigation investment, crop water usage is 111.53 m^3 per hectare higher than average crop water use when there is no private investment activity, holding all else constant (Colum VII, Row 18). Such a finding suggests that private investment may be taking place to aid farmers to exploiting greater supplies of water in the form of water distribution and extraction equipment such as diesel pumps, pipes and generators. Private investment could also increase water distribution efficiency, reducing seepage in the form of lined canals, thus moving higher volumes of water to the farm-plot level.

The *high-MRR level estimates under the IV models are* close to the estimates under the non-2SLS fixed effect models, indicating a robust result.

5.5.3.2. Crop yield and fiscal authority models

Levels of retention of irrigation revenues are not significantly associated with changes in crop yields. In the random effects models (Table 24, Set B), the models indicate an acceptable amount of explanatory power, with the variables used explaining 38% of variation in crop yields over the ten-year time period (Column V, Row 24). Several of the explanatory variables are statistically significant. In the full random effects models (Column V), results indicate that a village with private investment into irrigation infrastructure development produces 256 kilograms per hectare of wheat more per growing season, than a village without the presence of private investment, holding all other factors constant (Row 24). Villages in Henan Province have higher wheat production rate than villages in Ningxia, producing 597 kilograms per hectare more than the Ningxia average village, holding all else constant (Column V, Row 20). Farm plot size also explains crop yields (Columns I – V, Row 10). A one hectare per capita increase in average farm size is associated with 46 kilograms per hectare less seasonal wheat production.

Table 24 Set B: Impacts of fiscal & planning authority on crop productivity: village-level random effects

	Dependent variable: kilograms of wheat per hectare per season (kg / ha / season)							
		Random Effects					IV	
		I	II	III	IV	V	VI	VII
		β	β	β	β	β	β	β
1	High MRR * Investment Rate		13.059 (107.88)	21.700 (117.30)	13.922 (109.41)	24.848 (118.15)	-44.172 (111.67)	-35.021 (121.21)
2	High level of Marginal Retention of Irrigation Revenue (Dummy=1 if above average MRR)		-0.598 (1.868)	0.080 (1.946)	-0.663 (1.886)	0.099 (1.974)	-0.361 (1.858)	0.460 (1.972)
3	Village invests local funds to irrigation capital projects (Dummy=1 if yes)			-8.111 (105.07)		-5.999 (105.88)		49.954 (114.93)
4	Irrigation water price set by village (Dummy=1 if yes)			-127.98 (147.86)		-127.34 (151.406)		-146.427 (155.59)
5	Irrigation contracts signed by village (Dummy=1 if yes)			-86.332 (118.08)	-56.81 (175.21)	-82.375 (119.24)		-86.251 (128.245)
6	Irrigation fees collected by village (Dummy=1 if yes)			-239.46 (119.14)**		-270.35 (132.62)**		-271.39 (142.64)*
7	Allocation decided within village (Dummy=1 if yes)					-19.953 (180.74)		52.444 (190.57)
8	Delivery coordinated within village (Dummy=1 if yes)				-24.43 (103.23)	64.195 (115.967)		87.326 (128.71)
9	Surface water investment per hectare (RMB / ha, for time period)	-0.621 (0.650)	-0.546 (0.694)	-0.609 (0.720)	-0.550 (0.700)	-0.640 (0.729)	-0.735 (0.698)	-0.858 (0.741)
10	Sown area per capita (ha / capita)	-45.751 (25.124)*	-45.322 (25.33)*	-44.679 (27.13)*	-45.70 (25.59)*	-44.100 (27.417)	-46.292 (26.403)*	-44.50 (29.62)
11	Soil Type (Dummy=1 if soil type is xx)	135.717 (142.698)	135.39 (143.63)	172.15 (144.86)	135.19 (145.26)	167.07 (147.94)	103.777 (157.46)	122.377 (167.62)
12	Water user association (Dummy=1 if uses a wua)	27.703 (114.138)	27.094 (115.10)	192.96 (143.92)	49.306 (134.28)	174.53 (150.139)	35.206 (126.27)	157.03 (166.17)
13	Contract (Dummy=1 if uses contracting)	-48.538 (103.303)	-45.049 (105.17)	7.129 (118.048)	-34.346 (110.38)	-8.701 (122.170)	-56.376 (107.66)	-31.067 (126.05)
14	Number of laborers in village	0.097 (0.075)	0.097 (0.075)	0.126 (0.080)	0.096 (0.076)	0.128 (0.082)	0.115 (0.080)	0.142 (0.088)
15	Drought (Dummy=1 if drought reported during time period)	-136.86 (102.09)	-133.46 (104.08)	-124.98 (107.73)	-134.90 (104.81)	-124.96 (108.48)	-135.63 (107.64)	-142.86 (113.27)
16	Gross surface water irrigation stock (in 1,000 RMB, through previous time period)*	0.0002 (0.000)	0.0002 (0.0001)	0.0002 (0.000)	0.0002 (0.001)	0.0002 (0.0001)	0.0002 (0.0001)	0.0002 (0.000)
17	Only uses surface water for irrigation (Dummy=1 if yes)	193.43 (110.50)*	194.81 (111.36)*	168.17 (113.42)	198.04 (112.32)*	166.45 (115.22)	180.84 (121.85)	167.57 (127.26)
18	Private investment into irrigation infrastructure present in village (Dummy=1 if yes)	200.59 (89.76)**	201.11 (90.61)**	253.34 (119.16)**	198.65 (91.48)**	256.07 (120.78)**	167.85 (93.857)*	186.48 (130.02)
19	Village enterprise annual income (in real 2000 RMB)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)
20	Henan Province	678.26 (131.72)***	678.87 (134.02)***	603.09 (139.55)***	682.85 (135.13)***	596.62 (142.98)***	600.66 (146.90)***	545.24 (158.16)***
21	2001	36.928 (114.684)	38.734 (116.11)	23.984 (118.90)	50.757 (120.58)	19.57 (123.80)	21.786 (119.47)	6.215 (127.02)
22	2004	-52.015 (98.447)	-52.57 (100.26)	-36.783 (102.45)	-52.753 (101.23)	-38.039 (102.97)	-90.657 (104.73)	-75.464 (107.96)
23	Constant	2303.81 (200.04)***	2296.2 (202.81)***	2339.2 (206.73)***	2291.99 (204.30)***	2344.56 (210.23)***	2386.76 (224.74)***	2411.7 (233.77)***
24	R^2	0.354	0.354	0.379	0.355	0.380	0.339	0.366
25	observations	165	0.95	165	165	165	165	165
26	F-Test for joint significance of MRR variables			0.04	0.12	0.06	0.31	0.11
27	F-Test for joint significance of Fiscal Authority variables			4.48		4.58		1.02
29	F-Test for joint significance of Planning Authority variables					0.31		3.91

Across IV and non-IV random effects models estimating the impact of fiscal and resource planning authority on crop yields, one element of a village's fiscal structure appears consistently as associated with crop yields outcomes. In villages where village-level leaders (WUA leaders, WUA representatives, village leaders, contractors, etc.) collect the irrigation fees from the farmers, crop yields are less than villages where external irrigation agency staff collects the fees (Column 7, Row 6), holding all other factors constant. Overall, MRR, fiscal or resource planning variables as categories elicited no structural changes in crop yield outcomes.

5.5.3.3. Farmer income and fiscal authority models

Model Set C (Table 25), estimates how changes in a village's authority over irrigation's fiscal policy and resource planning impacts farmer income. To accomplish this, a fixed effects model is specified to control for unobserved time invariant factors at the village-level. An R^2 of 0.64 indicates overall good fit of model parameters to the sample village characteristics.

Table 25 Set C: Impacts of fiscal & planning authority on farmer income: village-level fixed effects

Dependent variable : annual per capita net farmer income

		Fixed Effects					IV	
		I	II	III	IV	V	VI	VII
		β	β	β	β	β	β	β
1	High MRR * Investment Rate		4.231 (3.523)	4.299 (3.760)	4.209 (3.545)	4.133 (3.790)	4.283 (3.545)	4.092 (3.903)
2	High level of Marginal Retention of Irrigation Revenue (Dummy=1 if above average MRR)		-495.41 (189.57)***	-514.91 (206.79)**	-513.16 (192.08)***	-511.62 (207.49)**	-497.26 (190.41)***	-457.33 (218.66)**
3	Village invests local funds to irrigation capital projects (Dummy=1 if yes)			-5.535 (179.28)		-23.741 (179.07)		227.166 (207.09)
4	Irrigation water price set by village (Dummy=1 if yes)			-86.800 (273.28)		-128.93 (276.88)		-17.554 (2.88.69)
5	Irrigation contracts signed by village (Dummy=1 if yes)			302.54 (216.79)		275.03 (217.16)		431.58 (233.49)*
6	Irrigation fees collected by village (Dummy=1 if yes)			120.68 (202.11)		259.281 (221.51)		201.79 (243.96)
7	Allocation decided within village (Dummy=1 if yes)				266.18 (313.48)	279.65 (331.69)		308.21 (367.62)
8	Delivery coordinated within village (Dummy=1 if yes)				-182.83 (169.67)	-266.66 (191.37)		-75.93 (228.10)
9	Surface water investment per hectare (RMB / ha, for time period)	0.616 (1.252)	-0.073 (1.258)	-0.209 (1.319)	0.061 (1.26)	-0.020 (1.322)	-0.212 (1.270)	-1.022 (1.415)
10	Sown area per capita (ha / capita)	78.22 (60.937)	77.090 (59.474)	59.551 (63.208)	68.850 (60.32)	48.548 (63.952)	80.335 (59.84)	25.686 (68.22)
11	Water user association (Dummy=1 if uses a wua)	-100.98 (215.90)	-164.42 (212.50)	-269.56 (258.003)	-82.61 (246.73)	-230.45 (273.046)	-226.574 (221.80)	-476.996 (324.89)
12	Contract (Dummy=1 if uses contracting)	-441.15 (181.51)**	-440.04 (182.19)**	-527.51 (195.97)***	-395.85 (197.96)**	-470.59 (207.93)**	-466.69 (185.13)**	-630.97 (222.54)***
13	Number of laborers in village	-0.328 (0.250)	-0.422 (0.247)*	-0.445 (0.264)*	-0.373 (0.250)	-0.374 (0.268)	-0.439 (0.250)*	-0.379 (0.288)
14	Drought (Dummy=1 if drought reported during time period)	-118.69 (174.22)	-55.102 (173.69)	-95.165 (182.86)	-39.129 (174.934)	-87.222 (184.10)	-74.558 (176.04)	-162.009 (194.18)
15	Gross surface water irrigation stock (in 1,000 RMB, through previous time period)*	-0.000 (0.0002)	0.000 (0.000)	-0.000 (0.000)	0.0000 (0.000)	-0.0001 (0.0003)	0.000 (0.000)	-0.000 (0.000)
16	Only uses surface water for irrigation (Dummy=1 if yes)	-89.746 (241.49)	-96.238 (241.29)	-91.916 (273.72)	-119.403 (243.23)	-89.913 (275.08)	-36.91 (248.53)	83.187 (340.91)
17	Village enterprise annual income (in real 2000 RMB)	0.0008 (0.003)	0.0005 (0.003)	0.002 (0.004)	0.0003 (0.003)	0.002 (0.004)	0.000 (0.003)	0.001 (0.004)
18	Private investment into irrigation infrastructure present in village (Dummy=1 if yes)	133.13 (161.33)	83.970 (158.58)	102.365 (218.81)	85.023 (160.64)	132.238 (222.41)	87.488 (159.33)	-38.702 (247.94)
19	2001	-1290.7 (189.51)***	-1316.1 (186.26)***	-1273.5 (199.52)***	-1337.3 (195.42)***	-1267.9 (209.64)***	-1340.2 (189.56)***	-1288.7 (234.03)***
20	2004	-1050.2 (152.86)***	-1018.6 (149.91)***	-994.627 (156.63)***	-996.85 (151.36)***	-969.89 (158.17)***	-1042.1 (153.0)***	-982.62 (182.73)***
21	Constant	3219.6 (436.80)***	3406.99 (433.52)***	3424.6 (454.08)***	3384.7 (433.88)***	3365.9 (454.03)***	3434.8 (440.59)***	3398.9 (506.3)***
22	R^2	0.599	0.626	0.630	0.634	0.641	0.626	0.640
23	observations	165	165	165	165	165	165	165
24	F-Test for joint significance of MRR variables		3.42**	3.14**	3.57**	3.06**	6.83**	4.45*
25	F-Test for joint significance of Fiscal Authority variables			0.54		0.72		4.7
26	F-Test for joint significance of Planning Authority variables				0.99	1.32		0.85

In the fixed effects models for the outcome of *net annual farmer income* (Columns I – V), aside from year variation, which confirms observations in the descriptive results that incomes, although still small, rose between 2001 and 2008, there are several other coefficients of interest. According to the model results, *contract management* is negatively and strongly associated with farmer income (Row 12). In villages that adopted contract management, farmer incomes declined by 470 Yuan per capita compared to pre-contracting average income (Colum 5, Row 12), holding other factors constant. In fact contracting is also associated with another irrigation development outcome, water conservation, where contracting style management in villages is associated with higher crop water use rates (Set A, Column IV, Row 12) than traditional collective management, holding other factors constant, confirming earlier results by Wang *et al* (2005). The prevalence of contracting as a significant predictor of irrigation development outcomes suggests that contractor's fee structure somehow results in higher overall water use, and perhaps higher levying of tariffs imposes higher costs to farmers, without contributing to any increases in agricultural yields.

The bureaucratization and re-centralization of irrigation line agency control over villages had a significant and positive impact on farmer incomes. On average, annual farmer net income, was 457 Yuan more per capita than the low revenue authority village average once villages conceded revenue authority to higher level agencies, holding all else constant (Column VII, Row 2), once correcting for endogeneity of revenue authority in the model via 2SLS. Additionally, to evaluate multiple parameters related to categories of policy-related variables, the null hypothesis that for all MRR related parameters, $H_0 = \beta_1 = \beta_2 = 0$, is tested implying that revenue authority policies as a category have no predictive power in the model.

Results of F-Tests comparing restricted versus unrestricted models reject the null of no predictive power of MRR variables as a category, indicating that revenue authority related variables have predictive power to estimate changes in annual net farmer income ($F=3.06$, $\alpha \leq 0.05$; Column V, Row 24).

5.6. Conclusion

This chapter reveals several important results from shifts in the locus of authority over irrigation provision in northern China's villages. First, upper level irrigation agencies are re-consolidating fiscal control, and taking local fiscal decision making out of the hands of village leadership and directly intervening in village-level irrigation projects. Although this re-consolidation of fiscal and resource irrigation planning authority is not resulting in water savings, it is reducing the "fee burden" of farmers and contributing to higher incomes. The direct intervention of the upper-level water agencies in village-level irrigation development, following the tax for fee reform is having on effect, although challenges remain in how to meet the national government's dual goals of saving water, while not impacting farmer incomes.

The revenue authority analysis also reveals that where villages retain contract type management, the local corporatism structure of the irrigation management hurts farmer incomes. Another way to interpret this is that the higher fees charged by farmers for agricultural water use is not resulting in crop revenue increases sufficient to off-set the higher irrigation water use rates. Although the survey does not explain why some villages continue to retain higher levels of discretionary spending funds in the hand of the village leadership and contractors, this finding underscores the government's recent decision to re-assert control over village –level irrigation finances.

As one looks at how shifts in environmental infrastructure impact water use, of particular importance in China's thirsty northern plains, this chapter finds that contrary to much water governance theory, local control and discretionary authority by local leadership fails to provide irrigation services that benefit farmers, or saves water.

Chapter 6: Conclusion

6.1. Introduction

Having reviewed evidence on the impact of fiscal decentralization on irrigation development in northern China, this chapter evaluates the hypotheses put forth in Chapters 4 and 5 and summarizes findings to answer the two research questions posed within those chapters. To recall, this dissertation sought to answer the larger question, how has China's decentralization policy impacted irrigation development? The dissertation ten explored two aspects of decentralization by focusing on village-level irrigation investment and asked: How do targeting and demand side factors drive different sources to invest in village-level irrigation development? How does the degree of local fiscal authority over irrigation funding impact village-level irrigation system performance?

Indeed, the overwhelming evidence presented in this dissertation confirms that fiscal structure impacts irrigation development – via diverse investment portfolios and localized authority over irrigation decision making – but not in the anticipated ways. Village-collective management lacked the capacity or resources to effectively manage irrigation systems and such a decentralized system left China's small scale irrigation works in shambles. To address this widespread structural decay of China's irrigation systems, descriptive and multivariate results show a clear re-centralizing of investment and irrigation management by upper-level irrigation agencies. The levers of control are shifting away from village collective control over irrigation management, and such shifts have large consequences for how village level irrigation works in northern China.

This chapter first revisits the study findings regarding the drivers of irrigation investment from three different funding sources. The next section reviews study findings on how local investment authority impacts village-level irrigation system performance, also referred to throughout the paper as irrigation development outcomes. Following this, possible strategies are proposed for policy makers to maximize the effectiveness of public and private investment into irrigation development, while also achieving the aims of increased crop yields, water conservation and increasing farmer incomes. Finally, the key theoretical findings of this study are discussed in terms of how this empirical work contributes to the fiscal decentralization and irrigation development literatures

6.2. Summary of findings

6.2.1. Study Overview

This dissertation set out to explain how the fiscal processes around irrigation infrastructure decision making result in a variety of village-level irrigation investment portfolios, and how decentralized fiscal structure impacts irrigation development outcomes of agricultural productivity, water conservation, and poverty alleviation.

Using fiscal decentralization and irrigation development theory, the preceding chapters reveal the how both upper-level government targeting strategies and local level demand side drivers determine public and private investment in village –level irrigation infrastructure. The study also investigates how local revenue and water planning authority impacts irrigation development performance by examining a number of different measures of village level authority, ranging from control over discretionary funds, to decision making over key financial aspects such as fee setting and contract signing, among others. Results from the empirical analysis show that securing a future water supply, by building infrastructure to access and store water, drives farmers to invest and that decentralized control over revenue and spending decision making matters significantly for water use and farmer incomes, but not in the ways hypothesized.

6.2.1.1. Drivers of diverse village level irrigation investment

Upper-level government is not following a progressive irrigation investment strategy.

A progressive irrigation investment strategy would follow the pattern of higher upper –level investment into villages with low-levels of irrigation development, and lower levels of funding to villages with highly developed irrigation systems. According to study results, the government is targeting investment funds toward increasing the quality of irrigated land in northern China but not expanding the quantity of surface water irrigated area. That is, upper-level government investment selection criteria are designed to target villages with higher levels of ability to irrigate land in their villages designated as 'effective irrigated area'. This targeting strategy departs from earlier strategies by the Chinese government to invest in irrigation development with the main aim to expand irrigated area (Cai 2010), but is supported by previous cost effectiveness studies that report that focusing on improving quality is a more effective irrigating development strategy than expanding irrigated area (Hayami and Kikuchi 1978). If the public investment strategy reflects the policy aim of increasing irrigated area in order to spur agricultural productivity and increase standards of living in rural areas (Huang, Rozelle et al. 2006), either the government struggles to reach under-served areas, or alternatively, focuses investment on villages with demonstrated capacity to maintain irrigated land. The targeting strategy appears to focus on increasing quality of irrigated land, rather than expanding the quantity of irrigated area.

Upper-level agencies allocate more to villages with unreliable water supply than the village collectives themselves.

As one looks to see what factors determine a village's irrigation investment portfolio, results indicate that unreliable water supply spurs investment from two groups, upper-level government and farmers, but not from the village collective. When considering the village-level and upper-level government policy priorities, this trend makes sense. Upper-level government not only makes investments to ensure economic and agricultural development, other priorities include poverty alleviation, and guaranteeing stable agricultural output throughout periods of natural disaster (including severe droughts), leading to the next major finding of the dissertation.

Farmers are reacting to water scarcity by investing private funds into infrastructure that secures water supply.

In villages utilizing only surface water resources for irrigation, farmers are willing to invest private funds toward irrigation infrastructure during drought periods, holding other factors constant. This finding presents a shift in the investment behavior of farmers in agriculture-related assets, an encouraging sign given the lack of clarity around canal ownership rights and previous dearth of private investment into fixed assets observed in the 1980s (Dong 2000). Ministry of Water Resources as recently as 2007 expressed desire to mobilize farmers to improve irrigation and water conservancy structure and note serious concern over lack of farmer investment into irrigation infrastructure (Wang 2007). Rural China's drive toward modernization requires the participation and investment of farmers, and according to these results, farmers, WUAs and contractors are contributing to this aim.

Results from this study suggest that farmers' increased investment activity is a response to increasing uncertainty around water supplies necessary to water crops. In recent years, the water reliability from canals has worsened and farmers have resorted to finding alternate supplies to augment water supplied via the surface water systems. Groundwater wells have proliferated (Zhang, Wang et al. 2008), and in places without groundwater, farmers appear to be investing into storage, pumps and piping in order to secure higher volumes of water from the system and store that water for use as needed for the crop watering schedule. Although this study does not investigate how farmers cooperate and organize funding strategies to build such infrastructures, this would be an interesting area for future research.

A second issue arising from the types of private and public investment portfolios found in this analysis is the lack of coordination and system-wide fragmentation resulting from such diverse sources developing along inter-connected surface water irrigation systems. Lack of clear ownership rights along canal systems has long been identified as leading to under-investment by villages and by farmers over water canals. Although property rights over canals still belong to the state and are managed by the irrigation districts, village-level operators gain a right to collect fees for service within the villages, leading to improved canal repair and upkeep of the small scale irrigation systems.

This set of canal responsibility clarifications may help explain the observed increases in private investment behavior. Clear ownership, as written up in contracts and operating agreements, designate responsibilities for upkeep and maintenance to specific parties, be they farmers, contractors, WUAs or village collectives. Once the responsibilities for maintenance and rehabilitation are tied to a specific responsibility party, in theory this leads to rights of fees associated with that canal system and motivation to improve the performance of those systems to keep revenues flowing. There is movement toward transfer of management rights to contractors and associations in the form of enterprises, joint-stock cooperatives and associations that have the right to manage and collect fees along the canal system, but clarity over the ownership designations along canal systems is necessary to spur private and village-level capital investment.

6.2.1.2. Impacts of local authority on irrigation development outcomes

Upper level irrigation agencies are taking local fiscal decision making out of the hands of village leadership.

A clear shift in the locus of decision making authority over village level surface water irrigation investments is observed, with increased revenue authority being held at the county and irrigation district level. The likely explanations for this behavior include village collectives' failure to invest much money toward irrigation infrastructure and in the cases where village collectives do invest, their projects to not reflect the water conservation mandates issued by the county and irrigation district governing agency, the Ministry of Water Resources. One can see that the highly decentralized irrigation provision system left north China's irrigation networks in shambles, and upper-level agencies are working to increase coordinated development and projects by re-consolidating control over irrigation development in China's villages.

Although the reasons underlying the re-consolidation of irrigation development decision making are beyond the scope of this dissertation, the 2002 tax-for-fee system marked a policy shift that constrained village collectives' ability to levy fees on villagers, and led to decreased discretionary funds in village collective budgets. In this way, the tax-for-fee system also removed many of the public goods provision responsibilities from the village collective. Public goods provision, including irrigation system investment, is now handled on a case –by- case allocation system, as managed by the irrigation district or county-level water resources bureau. This finding, combined with the determinants of private investment discussion above, suggests that going forward, upper-level irrigation agencies, WUAs, contractors and farmers will be the primary investors into village-level irrigation rehabilitation and upkeep. Given that the distribution of funds from the upper-level government agencies targets already developed areas, the development landscape will become more uneven as investments flow toward villages with existing high levels of capacity to irrigated their land.

Contrary to much water governance theory, discretionary control by village leadership failed to provide irrigation services that benefitted farmers

This finding speaks directly to the ongoing debate among environmental planners and political ecologists over the optimal locus of decision making over local water resource planning. For the case of irrigation development in China, this research shows that greater village-level authority over discretionary funds generated by irrigation fee revenue negatively impacts farmer income and that greater upper level government control over village irrigation investment projects, although not resulting in water savings, does reduce the "fee burden" of farmers and contribute to higher farmer incomes.

Reconsolidation of planning and fiscal authority benefits farmer incomes for two main reasons. First, although village collectives in China do not have the power to tax their citizens, up through 2002 they wielded discretionary power to levy fees for various services**.** The 2002 rural tax and fee reform eliminated local governments' power to levy fees on citizens in order to increases rural incomes. An unintended consequence of this reform was that provision of rural public goods declined, and villages and townships struggled to maintain day-to-day operation. Following initial implementation of the reform, the central government found itself facing massive declines in rural public goods provision, and in response to this latest development, the central government stepped up its direct involvement in the provision of public goods in the countryside.

Next, the direct involvement of Ministry of Water Resources' sub-agencies in village irrigation development introduces more modern technologies aimed at increasing efficiency and production on China's farms. The re-consolidation of investments suggests a secondary motivation on the part of the Ministry of Water Resources, not only to reduce the fee burden on farmers, but also to allow for direct involvement of irrigation engineers and professionals in village irrigation projects. The direct involvement of irrigation district professionals allows the regional irrigation agencies to coordinate projects throughout their service area, and also to align village projects with regional policy goals, such as conserving water or increasing crop yields. Although farmers have been slow to adopt many water saving technologies (Blanke, Rozelle et al. 2007), the government's unrelenting push toward agricultural modernization will be introduced to villages through irrigation district and county-level water bureaus' technical assistance and close cooperation with agency agriculture professionals.

6.2.2. Summary of findings

In summary, the two aspects of decentralization investigated in this study, diverse irrigation investment and authority over local discretionary fees from irrigation revenue, have become less decentralized in recent years. Ministry of Water Resources sub-agencies, namely county water resource bureaus and irrigation districts are taking back irrigation development control from the villages. These agencies appear to have targeted strategies for irrigation development investments that direct funds toward improving irrigation services in villages with existing high capacity to provide irrigation water to lands designated as irrigated area. Villages with low levels of irrigation development receive significantly less funding than villages that are able to irrigate their intended irrigated area. Investment activity by farmers and contractors is increasing compared with investment in the 1990s and early 2000s. Given this set of results, the state of decentralization in China's irrigation sector is shifting, toward a more hybrid approach to irrigation development involving irrigation agencies and farmers, contractors and WUAs, but bypassing the village collective.

6.3. Policy Implications

The findings of this dissertation are important because of the way they generate different kinds of insight into understanding why northern China's local irrigation projects struggle to achieve their desired outcomes. When a study is rooted at the level of the village, it is able to move away from sweeping generalizations of how villages operate and refocus attention on where much of the 'action' and diversity of China's irrigation sector is located, amongst village collective leaders, irrigation managers and farmers.

The conflicting priorities for northern China's rural development are stark in northern China. On one hand, the government recognizes the emerging water crisis and the threat of water scarcity's impact on economic development and food security (Wang 1999; Guoying 2002; Zhu, Giordano et al. 2004; He, Cheng et al. 2005). On the other hand, government policy continues to overlook long-term water resource availability constraints in order to secure the immediate livelihoods of farmers that rely on cheap groundwater and surface water for irrigation (Wang, Huang et al. 2006), and avoids measures to curb demand for irrigation water such as increasing the price of irrigation water (Feng 1999). Recent attempts to increase water savings via irrigation governance reforms at the village-level have not been widely accepted, nor have they achieved the anticipated water savings (Wang, Xu et al. 2006). Scholars and policy makers face no easy solution when it comes to enhancing the agricultural capabilities in the countryside, given the limited availability of arable land and present water constraints.

To achieve its irrigation development policy goals of conserving water, increasing crop yields and increasing farmer incomes, China's government changed the levers of control over fiscal and water resources planning in villages. This dissertation is the first study to empirically present this shift. Such changes in investment strategies, succeeded mainly in lowering the fee burden on farmers, but these shifts have yet to results in water savings or increased crop yields. Scholars have found that returns to public investment into agricultural research and development contribute the largest marginal gains to productive capacity and poverty alleviation for rural China (Fan, Zhang et al. 2002). While irrigation specific investments were found to have only moderate impact on overall productivity due to the smaller returns of agricultural than non-agricultural enterprises (Fan, Zhang et al. 2002), the potential benefits of upgraded irrigation systems not included in the study include potential gains to farmers in time-savings, water tariff savings, and supply reliability (in order to grow higher value, more water fickle crops). In order to realize these gains from investment however, infrastructure investments ought to be tailored closely to the local requirements of farmers and constructed in order to minimize overall water usage, while improving the timing and reliability of delivery.

Re-consolidation of fiscal and water planning investment authority by the water resources bureaucracy re-introduces irrigation engineers and professionals into village irrigation development at a critical time in northern China's rural development. Land and water quality degradation over the last 20 years of China's industrialization, coupled with village and farmers' reliance on traditional farming methods, has left China's grain supply vulnerable to extreme weather, water shortages and vermin. The impacts of fiscal re-concentration, as noted above, are intended not only to control funding, but have a greater organizational aim to allow for direct involvement and oversight by irrigation professionals into village irrigation development and operational activities. This movement away from an 'every village for itself' self-sufficiency development model, allows the agencies to coordinate and strategically plan for regional irrigation development.

Although results indicate farmers' willingness to invest capital, with a likely expectation of returns on investment, results also present a host of new policy issues for local and regional governments. First, capital investments such as pumps, new canals and diesel engines, in addition to digging mini reservoirs, indicate the proliferation of more localized water supply systems, which may benefit the village with storage and distribution capacity, but also result in decreasing availability of water for neighboring villages, especially those downstream. Within the regional or river basin level system, downstream users may receive less water as upstream users secure higher volumes of the fixed water supply to store in ponds and tanks. Evidence is emerging that farmers in China are investing heavily in on-farm water storage, to respond to uncertainty in surface supply, capture more runoff and return flows, and allow flexibility in scheduling (Molden, Bin et al. 2005). Such patterns indicate a need for greater regional planning and supervision to guarantee supply for all users along branch canal systems.

What are the best ways to achieve gains in agricultural efficiency in a way that also enhances rural livelihoods? Regardless of the source, investment into irrigation infrastructure has the potential to increase incomes in three ways. First, by decreasing the water volume requirement and overall expenditure on water so that the overall private input cost per crop production unit is decreased.[17] Second, by freeing

[17] It is acknowledged that with a lack of farm plot level volumetric pricing, this income gain may only be realized at the village-level when the village water manager receives an incentive to reduce water consumption. Wang, J., Z. Xu, et al. (2006). "Incentives to managers or participation of farmers in China's irrigation systems: which matters most for water savings, farmer income, and poverty? ." Agricultural Economics **34**(3): 315-330.

up labor required to wait for unreliable water supply, and time spent locating alternative water sources, so that this labor can be allotted to non-agriculture related enterprises, including small businesses, wage labor, and education[18]. Third, improved water reliability allows farmers to move away from low priced grain production, to grow higher value crops such as field vegetables, fruits and other cash crops that have more specific watering requirements and generate higher returns on inputs (Gommes 1997). The increasing territoriality over water provision by farmers is a trend that needs immediate attention by regional water planners.

6.4. Key theoretical findings and contributions

In addition to direct policy implications, this research represents an important contribution from a theoretical standpoint towards 1) understanding the role of water scarcity in public and private investment behavior and 2) assessing how shifts in fiscal and water planning authority over irrigation investments contribute to local irrigation development and 3) the impacts of decentralization on distribution of investment.

This first key theoretical implication of this study's findings is that despite upper-level government investment into village's irrigation infrastructure, under water scarce conditions farmers invest their private funds into infrastructure provision. Scholars of irrigation investment in lesser developed nations have found that when governments provide large capital investments in common pool goods, individuals

[18] Fan, Zhang et al 2002 find that investments in education lead to the highest reductions in rural poverty in China. Therefore the opportunity cost for labor becomes higher as it takes children away from education, and adults away from other forms of technical training.

will not contribute their personal money to building or maintaining such goods (Ostrom, 2002). Results from this study challenge existing knowledge on farmers' (private) irrigation infrastructure investment behavior by showing that farmers facing water uncertainty, in the form of drought and limited water supply options, are willing to investment private money toward irrigation infrastructure development.

Clear canal ownership designation when canals are managed by WUAs and contractors also increases the likelihood that farmers will invest their funds into upkeep and development of the village canal system. This finding support previous work on the importance of ownership rights to incentivize private investment (Kung 1995; Lohmar, Wang et al. 2003), and introduces findings on ownership structure into China's irrigation development scholarship. This movement towards a quasi-privatized irrigation services system under the management of a profit-driven irrigation contractor differs from ownership models in other developing countries. Although the responsibility and ownership structures are more clear than under the village collective system, privatized irrigation services appear to hurt farmer incomes and is a rich area for further research.

The second important and related theoretical implication of this study is that a hybrid regional investment and irrigation planning model, involving regional irrigation agencies and farmers, results in better outcomes for farmers than village collective management of the irrigation system. This finding adds to a growing literature over the spectrum of decentralization present in managing environmental resources in the developing world (Ribot, Agrawal et al. 2006) and in particular supports other studies questioning the ability of local governments to handle the job of local resource management (Larson 2002). Prior to 2002, China's decentralized irrigation development model placed the village collective leadership in control of village irrigation management, investment and operations with little concern over their capacity to effectively manage irrigation. The village collective's responsibility over irrigation management failed due to several reasons namely: 1) rent-seeking from irrigation fees (Repetto 1986), 2) lack of expertise in irrigation technology and management (Blanke, Rozelle et al. 2007), 3) lack of funds to maintain and build infrastructure (Huang, Rozelle et al. 2006) and 4) lack of financial incentives to invest into agriculture-related infrastructure (Oi 1999; Faguet 2002). This fiscal and planning decentralization style of village collective management of irrigation left China's irrigation infrastructure in ruins, while also hurting farmers by levying innumerable fees on farmers as a revenue source for village collective budgets. According this study's descriptive and analytical findings, a gradual transition to direct cooperation between irrigation agencies and farmers has increased farmer incomes, and certainly has the potential to lead to long-run transitions to more modern and efficient farming practices. The fiscal style of irrigation infrastructure provision matters for creating an agricultural environment that works for farmers, and keep farmers on the land growing the food that sustains China's growing appetite.

The question asked by many scholars of decentralization is who benefits and who loses under a decentralized fiscal system? For the case of irrigation development in China, this study adds to a body of theoretical work contending that decentralized fiscal frameworks are not progressive and that less-well-off villages receive fewer funds from the central government and continue to invest less under decentralization

(Faguet 2002; Zhang 2006). Thus supporting a skeptic's view of the dangers of decentralization (Prud'homme 1995) However, how decentralization impacts equity and efficiency in the case of irrigation development may require a different means of assessing disparity than income disparity measures due to limitations on water resources across the region. Studies in the Philippines found that investment into increasing the quality of irrigated land was more cost effective than investing to equalize irrigated land holdings across villages by expanding irrigated area (Hayami and Kikuchi 1978). The natural resource dependence of irrigation development makes the study of disparities and distribution different than simply studying income and wealth distribution. Assessing how distribution of irrigation development investment funds contributes to larger scale benefits, such as regional, river basin or national, would be a valuable area for future research.

APPENDIX A: Instrumental variable diagnostics

Table 26 Instrumental variable diagnostics

diagnostics	*dependent variable:*	**Water Use**	**Crop Productivity**	**Farmer Income**
IV1 weak instrument?	t-statistics	results: * The instruments are jointly significant (p<0.0000) and the r-squared is high (.17), so proceed with the IV.	results: * The instruments are jointly significant (p<0.0000) and the r-squared is high (.17), so proceed with the IV.	results: * The instruments are jointly significant (p<0.0000) and the r-squared is high (.17), so proceed with the IV.
IV2 valid instrument?	Hausman	results: The Hausman test rejects the exogeneity of mrr_hi since the p-value (Prob>chi2) <.05 (prob=0.0005)	results: The Hausman test rejects the exogeneity of mrr_hi since the p-value (Prob>chi2) <.05 (prob=0.0188) */	results: The Hausman test rejects the exogeneity of mrr_hi since the p-value (Prob>chi2) <.05 (prob=0.0323)
IV 3 properly identified?	Over Identification tests	The p-value of the chi-squared statistic (p=.01) indicates that in fact the instruments PERFORM WELL IN the over-identification test. Thus the IV and above Hausman results are correct	The p-value of the chi-squared statistic (p=.01) indicates that in fact the instruments PERFORM WELL IN the over-identification test. Thus the IV and above Hausman results are correct	The p-value of the chi-squared statistic (p=.01) indicates that in fact the instruments perform well in the over-identification test. Thus the IV and above Hausman results are correct. For income, village leader education failed to be a valid instrument, so we remove this one

APPENDIX B: Crop productivity and crop water use calculation procedures

<u>C1. Calculation Procedure for agricultural productivity of surface water irrigated land in North China Irrigation Management Data 2001-08.</u>

To calculate *kilograms per irrigated hectare for surface water wheat yields* for 2001, 2004, and 2008, I follow the following procedure.

Based on 2001-2008 data from the village form survey and surface water management form, we can systematically calculate crop productivity rates for each village in the sample. The data is from the village form section D which contains a breakdown of the crop production per area divides between irrigated and non-irrigated village land holdings.

Steps:

1) Select forms D from Village Forms from three data sets: Ningxia 2004; Hebei and Henan 2004; village forms 2001. Copy into new Data form for calculating crop productivity in variables folder of dissertation proposal.

2) Synchronized variables between a) sections D in Ningxia Henan and Hebei for 2004 data forms; b) section D between 2001 and 2004.

3) Standardize crop codes between all data sets. Crop codes changed between 2001 and 2004. I update 2001 dataset to 2004/08 codes.

4) Village form does not have local crop prices for 1995 – 2001. Ask to use Household survey to create average crop price data base for 2001 –Table E (this step not relevant for yield measures).

5) To find per mu value, multiply RMB per JIN * JIN per MU = RMB / MU. The convert MU to hectare.

6) Next, calculate rate of kilogram per actual irrigated area.

C2. Crop water use measurement procedure for village-level survey results from North China Irrigation Management Data 2001-08.

To calculate *cubic meters of surface water per irrigated hectare per growing season* for 2001, 2004, and 2008, I use the following procedure.

The village crop water use patterns are recorded in several different ways depending on the villages' irrigation system specifications. A surface water manager could report water use as: gravity irrigation by area, gravity by volume and, pumped irrigation, I each of the irrigation methods in order to get a rate of water use per area of irrigated land, for wheat crops.

Steps:

1. Gravity irrigation by volume. Calculated as: m^3/mu/app* # apps/period = m^3/mu/growing period;

2. Pumped surface water irrigation. Calculated as hour/app/mu*m^3/hour*#apps/period = m3/mu/growing period;

3. Gravity irrigation by area. Field area(cm^2)*waterdepth (cm)/1000000 * 1/irrigated area;

4. Sum water use for season by adding water per application (cubic meters per season);

5. Divide total water applied by irrigated area;

6. Convert units to be standardized to a cubic unit of water per irrigated area.

Notes. The crop water use measures, when comparing them to household level crop sales, we can see that the majority of water use goes toward grain that is not sold but used for household or to fulfill grain quota. Therefore the water data collected does not cover where a farmers' discretionary water use is going, that is what smaller cash crop the farmer plants to make a living/profit. These would be difficult to measure 1) because they are often intercropped or shared in with wheat / corn; and 2 because both the water amount and precision of measure is low. Further studies on the highest economic use of irrigation water crop water must integrate these smaller scale crops. Where we can measure which crop requires the lowest water use for the highest a. volume; b. return per volume

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