Privatization of tubewells in North China: Determinants and impacts on irrigated area, productivity and the water table

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Abstract Despite the rise in importance of the private sector in the expansion of the use of groundwater in China and the potential implications this might have for production and poverty, little has been written about the effect of these phenomena on northern China's economy. In examining determinants of tubewell privatization and its impact on producers in northern China, data were collected using a community leader survey, carried out in 448 villages in six provinces in northern China. The results show that since 1990 collective ownership of tubewells has largely been replaced by private ownership. Increasing water scarcity, government grants and bank loans for tubewell investment and the declining investment capacity of China's local communities have led to the observed change in tubewell ownership patterns. By far, the most important positive effect on income appears to be due to the expansion of newly irrigated area that has been fueled by the rise of private tubewells. Many newly private tubewells also have begun to replace irrigation from surface water sources. While helping increase income and productivity, the rise of private tubewells also has contributed to the fall in groundwater levels.

Résumé Malgré l'importance grandissante du secteur privé dans l'expansion de l'utilisation de l'eau souterraine en Chine, et l'implication potentielle qu'elle aurait sur la production et la pauvreté, peu de choses ont été écrites sur l'effet de ce phénomène sur l'économie du Nord de la Chine. En examinant les déterminants de la privatisation des puits et ses impacts sur les producteurs, des données ont été collectées via des enquêtes sous la tutelle des chefs de communauté, dans 48 villages de six provinces du Nord de la Chine. Les résultats montrent que depuis 1990, la propriété collective des puits a été largement remplacée par la propriété privée. La croissance de la pénurie de l'eau, les subventions gouvernementales, les prêts bancaires pour l'investissement dans les puits, et le déclin de la capacité des investissements des communautés locales chinoises, a conduit à des changements dans les schémas de propriété des puits. De loin, l'effet positif le plus important est le produit due à l'expansion de nouveaux périmètres irrigués alimentés par l'augmentation des puits privés. De nombreux et nouveaux puits privés ont également commencé à remplacer l'irrigation par puits privés. Alors qu'elle a aidé à augmenter les recettes et la productivité, l'augmentation des puits privés a également contribué à la baisse des niveaux piézométriques.

Resumen A pesar del ascenso en importancia del sector privado en la expansión del uso del agua subterránea en China y las implicaciones potenciales que esto podría tener para la producción y pobreza, se ha escrito poco acerca del efecto de estos fenómenos en la economía del norte de China. Al examinar las determinantes de la privatización de pozos entubados y su impacto en los productores del norte de China, se colectaron datos utilizando un levantamiento líder de comunidades, llevado a cabo en 48 poblados y seis provincias del norte de China. Los resultados muestran que desde 1990 la propiedad colectiva de pozos entubados ha sido ampliamente reemplazada por propiedad privada. La creciente escasez de agua, apoyos gubernamentales y préstamos de bancos para inversión en pozos entubados y la declinante capacidad de inversión de las comunidades locales de China ha llevado al cambio observado en los patrones de propiedad de pozos entubados. Cuando mucho, el efecto positivo más importante en los ingresos parece deberse a la expansión de un área de riego nueva que ha sido alimentada por el incremento de pozos entubados privados. Muchos pozos entubados nuevos privados también han empezado a reemplazar el riego que se abastece de fuentes de agua superficial. Mientras que por un lado el incremento de pozos entubados privados ha ayudado a incrementar los

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ingresos y la productividad por otro lado también ha contribuido al descenso de niveles de agua subterránea.

Keywords Tubewell ownership · Privatization · Determinants · Impacts · China

Introduction

The economy of North China has expanded rapidly over the last 50 years, and the region now forms one of the main economic and political centers of China. Since the 1950s the region's gross domestic product (GDP) has increased more than 10 times (China National Bureau of Statistics 2002). Both rural and urban areas have contributed importantly to the growth. Agricultural GDP has risen by more than 5 times. Wheat and maize yields have increased by nearly 7 and 4 times respectively during the past 50 years and output grew by more. Facing changing demand for agricultural products in both domestic and export markets, farmers also have begun to shift from staples into cash crops. The development of the region also made a positive impact on poverty; the poverty rate fell from around 30% in 1985 to less than 10% in 2001 in many provinces in northern China (Wang 2004).[1]

During the past 50 years, improvements in water control—in both surface and groundwater—initially played a major role in improving living standards, expanding industrial output and raising sown area and yields, although the mix between surface water and groundwater has changed over time. Most of the increase in water availability in northern China came from the expansion of surface water systems, constructed during the 1950s and 1960s. China's leaders invested in building reservoirs, constructing new canal networks and increasing the utilization of the region's lakes and rivers. By the end of the 1970s, most of the available surface water was already being utilized in most basins in northern China; the area irrigated by surface water more than doubled on the North China Plain (Nickum 1988). However, because of poor management and lagging investment, especially in maintenance, many surface water canal systems began deteriorating in the 1980s (Lohmar et al. 2003). The efficiency of delivery of many of the remaining surface water systems was also thought to be low, at around 25–40% (Xu 2001). Poorly designed surface water systems have led to salinization and other environmental problems (Nickum 1988).

Faced with deteriorating and increasingly scarce surface water resources, farming communities in northern China began to turn to groundwater in the late 1960s and 1970s. From almost nothing in the 1950s, official statistical sources show that by 1997 producers were abstracting groundwater from 3.5 million tubewells and irrigating nearly 15 million hectares, mainly in North China (Ministry of Water Resources 2000). According to national statistics, although only about one-third of China's groundwater resources are in northern China, more than 87% of groundwater use is in northern China. In the late 1990s, about 40% of northern China's water came from groundwater resources. According to Wang et al. (2005a), the expansion of tubewells and use in agriculture began accelerating in the mid-1990s. In addition, in more and more cities residents are relying on groundwater for their domestic needs. In an increasing number of regions, industries are relying on groundwater for production purposes.

Beyond its rapid expansion, one of the most intriguing characteristics of the groundwater sector—especially in recent years—is the emergence of the private sector in nearly all aspects of water management. In a survey of a set of villages in the Hai River Basin (HRB), Wang et al. (2005b) found a rapid shift in the ownership of tubewells occurring; between 1983 and 1998, the share of the collective wells fell from 93% to 36%. In the past only state-owned well drilling companies had the equipment and permission to drill wells. Today, however, visitors to the countryside cannot help but see uncountable advertisements for the services of private tubewell drilling services. The market for pumps also is clearly shifting from a state-owned enterprise-dominated market to one in which there are many private sales outlets and salespersons (Huang et al. 2004). Zhang et al. (2005) observed that groundwater markets within villages are increasingly being run by private individuals.

Despite the pervasiveness of the rise in groundwater use, in general, and the emergence of the private sector in the groundwater economy, in particular, little has been written about the effect of these phenomena on northern China's economy. Because of disruption effects and differences in access to output and revenue flows, economists studying privatization, in general, are frequently worried about how the transfer of ownership rights will affect agricultural output, productivity and income (Li and Rozelle 2004). In the groundwater sector in China's agricultural economy, with the exception of Wang et al. (2005b)—which examines the rise of tubewell privatization in a small subset of villages in three counties—there is almost nothing published on the rise or impact of the large scale privatization of tubewells that is now occurring in northern China.

There also has been little empirical analysis that has tried to document the effect that the rise of groundwater use and recent privatization trends have had on the level of the groundwater. In the literature on China today, one of the most commonly raised concerns is about the long term sustainability of current water use rates. For example, in Feixiang County (Hebei province)—located within the Fuyang River Basin (within the HRB)—the shallow groundwater level fell by 0.6 m/year during the 1980s and 1.3 m/year during the 1990s. Even greater rates of decline appear to have occurred in the shallow water table of the lower Fuyang basin. Similar excessive water withdrawals and falling groundwater levels have caused land subsidence in some rural areas, cones of depression under some cities

[1] In the rest of this paper, "northern China" refers to 12 provinces in north, northeast and northwest China. The provinces include Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Shandong, Shanxi, Henan, Shaanxi, Qinghai, Ningxia and Gansu. The two municipalities are Beijing and Tianjin. Note, in this analysis because of the lack of information on provinces in the extreme western areas of China, Tibet and Xinjiang are not included.

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and deteriorating water quality near the coast (Hebei Hydrological Bureau and Water Environmental Monitoring Center 1999). There is a perception that the rate of the fall of the groundwater levels is accelerating over time. The coincidence of privatization trends and the increasing rates of fall of the groundwater level logically lead to concerns of causality. Despite the importance of such issues, only a small number of papers have addressed these issues (e.g., Wang et al. 2005b). Moreover, there are no papers that have examined the effect of privatization using nationally (or regionally) representative data. In fact, in all of the previous literature, there has not been a full discussion of the mechanism that might create a linkage between the rise of private tubewells and the fall of the groundwater level.

The overall goal of this study was to examine how the evolution of groundwater governance in northern China has affected the rural economy in terms of its effect on production, income and the water table. To do this, two data sets were first used—one regional data set with relatively long times series; and one that is regionally representative of northern China—to describe the evolution of tubewell ownership throughout northern China.[2] Second, the study examined the nature of the villages and households in the regions in which privatized tubewells have emerged and the factors that appear to have influenced their rise. Third, after considering the various ways that privatization might affect irrigated area, production, income and the water table, the paper explores empirically its impact. The paper ends with a discussion of the implications of the findings for policymakers.

Methods and data collection

The data for the study came from two sources. The first part of the data was derived from a survey conducted in 48 villages in Hebei and Henan Province in 2001 and 2004 (henceforth called the China Water Management Survey or CWMS), shown in Fig. 1. Although not representative at the national level, because of the use of recall techniques and repeated visits over time, enumerators have been able to collect a relatively long term series of information. The enumerators collected data for 1990, 1995, 2001 and 2004.[3] Despite not being representative, the counties and villages were randomly selected. The data set also is relatively rich in that it contains information not only from village leaders, but also from tubewell owners, managers and farmers. Much of the data from earlier periods came from written records kept by the village accountant.

[2] In the rest of the paper, when referring to the evolution of ownership or the shift in ownership, there are two different, but related, processes occuring. One involves the sale or transfer of ownership rights from the collective to a single or group of private individuals. The other involves the decision to invest in a new tubewell for the private individual instead of the collective.

[3] The sample includes Hebei and Henan provinces, which covers both the Hai River Basin (HRB) and the Lower Reaches of the Yellow River Basin (LRYRB).

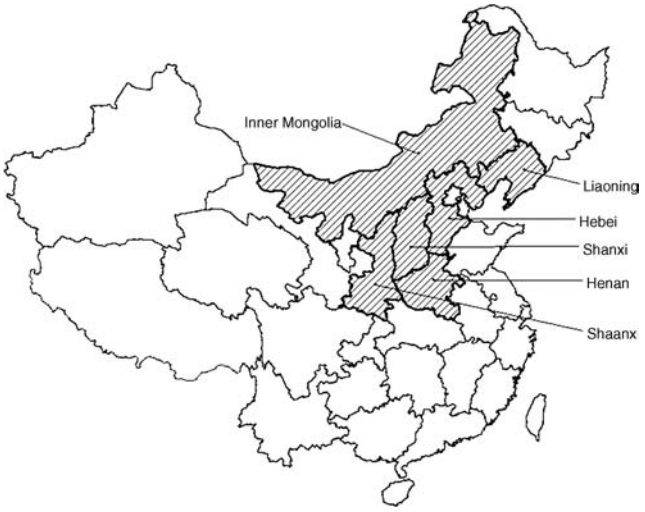

Fig. 1 Location of survey provinces in North China. Note: The China Water Management Survey (CWMS) covers two provinces: Hebei and Henan Provinces; the North China Water Resource Survey (NCWRS) covers six provinces: Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi provinces

One of the main purposes of the survey was to understand the differences between two types of groundwater governance for tubewell ownership: collective and private. As such, the survey instruments (questionnaires) and enumerators carefully defined governance. If a village's leadership council owned a tubewell, the tubewell was defined as *collective*, otherwise it was defined as *private*. Within the private tubewell category, two forms exist. Tubewells belonging to a single individual or family are defined as *individual-ownership tubewells*. Those owned by groups of individuals are defined as *shareholding tubewells*. This name is derived from the fact that individual members are (implicitly or explicitly) assigned shares indicating the investment stake of each member. In executing the village questionnaire, enumerators asked village leaders to recall the total number of operating tubewells by ownership type in each of the survey's four target years.

The survey also collected information used to understand the determinants of tubewell ownership and several measures of the effects of ownership shifts on crop productivity, income and water resources. The determinants of tubewell ownership included several possible determinants of tubewell ownership, such as, the scarcity of water and the per capita income level of the village. Water scarcity is defined as the depth to the water table in a tubewell after at least three months of non-use (typically in the Fall season). Enumerators asked village leaders whether the government provided either fiscal subsidies or bank loans for aiding the collective or individuals to invest in tubewells. Enumerators also recorded cropping patterns (the share of overall sown area accounted for by each crop) and crop yields to assess productivity impacts. In addition, enumerators collected information on per capita farmer income to assess the income impacts of changes in the institutional environment, if any.

Because the sample in the CWMS survey was not representative of northern China, in December 2004 the

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research team undertook another survey effort, the North China Water Resource Survey (NCWRS). This survey of village leaders and accountants from more than 400 villages in Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi provinces used an extended version of the community scale village instrument of the CWMS survey (Fig. 1). The sample was chosen using a stratified random sampling strategy for the purpose of generating a sample representative of northern China. To choose such a sample, the survey first sorted counties in each of the regionally representative sample provinces into one of four water scarcity categories: very scarce, somewhat scarce, normal and mountain/desert. The survey team randomly selected two townships within each county and four villages within each township. In total, combining the CWMS and NCWRS surveys, the survey team visited approximately 6 provinces, 60 counties, 126 townships and 448 villages.

The scope of the surveys was quite broad. Each of the survey instruments included more than 10 sections. Among all of the sections, there were those that focused on the nature of rural China's water resources, the common types of well and pumping technology, several sections that examined the most important water problems confronting groundwater villages, government policies and regulations. There were two sections devoted to groundwater governance. Although sections of the survey asked about both surface and groundwater resources, enumerators focused mostly on those villages that have groundwater resources (in some cases, whether they were using them or not). The survey collected data on many variables for two years, 1995 and 2004. By weighting descriptive and multivariate analysis with a set of population weights, point estimates for all of northern China could be generated.

Privatization of tubewell ownership

Tubewell ownership in the CWMS study area shifted sharply from collective to private (Table 1). In 1990 collective ownership in the Hebei and Henan sample counties accounted for 51% of all tubewells. Between 1990 and 2004, however, the collective ownership of tubewells diminished to 19%; during the same period the share of private tubewells increased from 49% to 81%. While the shift of tubewell ownership occurred throughout the entire sample, its pattern varied across the study counties and among villages within the counties.

Within the private sector, there also are differences over time in the composition of ownership. During the 1990s, individual-ownership tubewells accounted for most private tubewells, 83% of private tubewells were invested in by individual households (Table 1). Shareholding tubewells began to exceed individual-ownership tubewells after the late 1990s. In 2004, the share of individual-ownership declined to 36%; while the share of shareholding ownership increased to 64%, dominating the patterns of private ownership.

The shift of tubewell ownership has come mostly from the establishment of new tubewells (Table 1). Between 1990 and 2001 the number of collective tubewells in the sample villages remained fairly steady, and, in fact, grew somewhat between 1995 and 2001 (rising from 740 to 814). After 2001 the total number of tubewells began to fall (from 814 in 2001 to 636 in 2004). At the same time, the total number of private tubewells increases by nearly 4 times, rising from 722 in 1990 to 2721 in 2004. The increase of private tubewells mostly came from shareholding tubewells. From 1990 to 2004, the number of shareholding tubewells increased more than 14 times.

Unfortunately, the CWMS study method cannot identify the nature of the growth of private tubewells over time (in addition to not being able to track what is happening in northern China, in general). With the NCWRS, however, the study has acquired more detailed information across a wider region. Despite the differences in the sample, the patterns of privatization and absolute growth in the number of wells are similar (Table 2). According to the NCWRS data, in 1995, 46% of tubewells were collectively owned in North China. By 2004, the percentage had fallen to only 31%. Such a pattern of a falling percentage of collective tubewells occurs in all of the sample provinces. However, the NCWRS data show that, except for Hebei province, the individual ownership is the main form of private ownership. Apparently, shareholding is an institutional arrangement that is mostly found in Hebei Province.

In addition (and also like the CWMS), the rising share of private tubewells is mostly due to the absolute expansion in the number of new private wells (Table 2). Although in the NCWRS sample the number of collective wells rose (by 26%, from 2990 in 1995 to 3756 in 2004), the number of private wells expanded more in both absolute and percentage terms. Between 1995 and 2004, the total number of private wells grew from 3508 to 8176, a rise of 233%. Interestingly, while private tubewell use expanded between 1995 and 2004 in all provinces, more than 80% of the rise occurred in Inner Mongolia and Liaoning. In addition, except for Hebei Province, the expansion of private tubewells mostly came from individual-ownership tubewells.

While most of the rise in private tubewells was "*denovo*" (a local term; the investment and management of the drilling and installation of the well was completely done by private farmers), the data show that a rising share also was due to the privatization of collective wells (Table 3). In the 2004 NCWRS survey, enumerators asked the respondents to provide two pieces of information about each tubewell—firstly, who initially invested in the tubewell, and secondly, who currently has ownership rights?[4] According to the findings of the survey in 1995, of the 2672 tubewells that had been originally invested in by the collective, 358 of them (or 13%) had been sold to shareholding groups (5.5%) or private individuals (7.5%). In 2004, the rate of privatization had risen. Of the 3464 wells that had originally been invested in by the collective, 821 (or 23%) had been privatized (19% to individuals). Despite the rise

[4] In fact, the question asked specifically about alienation rights, that is, if the tubewell was sold, who would make the decision and who would receive the proceeds of the sale).

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Table 1 Changes of tubewell ownership in Hebei and Henan Province, 1990–2004

Year	Collective vs private			Within private		
	Total	Collective	Private	Total	Shareholding	Individual
Share of tubewells (%)						
1990	100	51	49	100	17	83
1995	100	40	60	100	44	56
2001	100	22	78	100	55	45
2004	100	19	81	100	64	36
Number of tubewells						
1990	1464	742	722	722	120	602
1995	1854	740	1114	1114	494	620
2001	3656	814	2842	2842	1567	1275
2004	3357	636	2721	2721	1728	993

Data source: Authors' surveys in 48 randomly selected villages in Hebei and Henan Province (CWMS)

Table 2 Changes of tubewell ownership in North China, 1995–2004

Year	Collective vs private			Within private		
	Total	Collective	Private	Total	Shareholding	Individual
Share of tubewells (%)						
1995						
North China	100	46	54	100	14	86
Hebei	100	64	36	100	80	20
Henan	100	93	7	100	12	88
Shaanxi	100	88	12	100	2	98
Shanxi	100	91	9	100	0	100
Inner Mogolia	100	60	40	100	41	59
Liaoning	100	11	89	100	0	100
2004						
North China	100	31	69	100	13	87
Hebei	100	48	52	100	98	2
Henan	100	84	16	100	11	89
Shaanxi	100	46	54	100	1	99
Shanxi	100	79	21	100	9	91
Inner Mogolia	100	40	60	100	17	83
Liaoning	100	8	92	100	0	100
Number of tubewells						
1995						
North China	6498	2990	3508	3508	506	3002
Hebei	904	582	322	322	259	63
Henan	575	534	41	41	5	36
Shaanxi	471	413	58	58	1	57
Shanxi	340	308	32	32	0	32
Inner Mogolia	1421	858	563	563	231	332
Liaoning	2787	295	2492	2492	10	2482
2004						
North China	11932	3756	8176	8176	1036	7140
Hebei	1267	610	657	657	643	14
Henan	860	722	138	138	15	123
Shaanxi	553	255	298	298	2	296
Shanxi	382	302	80	80	7	73
Inner Mogolia	3548	1419	2129	2129	356	1773
Liaoning	5322	448	4874	4874	13	4861

Data source: Authors' survey in 400 villages of six provinces in North China (NCWRS)

in privatization, however, privatized wells still made up on a small fraction (12% or 821 of 7140) of all private wells. From this, it is clear that denovo private wells have accounted for a large share of the rise of wells since the mid-1990s.

Tubewell ownership, resource scarcity and rural reform

Scholars in recent years have analyzed the determinants of institutional innovation both theoretically and empirically.

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Table 3 Privatization of collective tubewells in North China, 1995–2004

	Tubewells invested by collective			
	Total	Collective tubewells	Shareholding tubewells	Individual-ownership tubewells
1995				
North China	2990	2672	148	210
Hebei	582	430	139	13
Henan	534	578	0	0
Shaanxi	413	413	0	0
Shanxi	308	308	0	0
Inner Mogolia	858	728	9	117
Liaoning	295	215	0	80
2004				
North China	3756	3464	152	669
Hebei	610	445	145	20
Henan	722	1231	0	0
Shaanxi	255	275	0	0
Shanxi	302	252	0	50
Inner Mogolia	1419	896	7	516
Liaoning	448	365	0	83

Data source: NCWRS in 2004

For example, White (1995) finds that government policies, the degree of democratization and financial market liberalization play important roles in institutional change. Otsuka (1995) shows that in much of the empirical literature, environmental and population factors, government policies and other socio-economic variables are the main determinants of institutional change. Tang (1991) and Uphoff (1986) have identified three factors—physical and technical characteristics of the resource, characteristics of the group of users, and attributes of institutional arrangements—which influence water management institutions, in particular.

While little empirical work has focused specifically on groundwater, the international literature has identified several factors that affect tubewell ownership. Based on a case study of tubewell ownership innovation in Pakistan, Meinzen-Dick (1996) concludes that the emergence of private tubewells is mainly due to the changes of groundwater and surface water utilization, farm scale and population density. Shah (1993) shows how the emergence of institutions that encourage water sales in villages has levered the rise in private tubewell ownership. Barker and Molle (2002) point to the increased availability of reliable pumping technology and hint that this has been a factor in increasing the rise of private tubewell ownership in South and Southeast Asia. Despite the importance of groundwater in China's agriculture and its rapid evolution over time, almost no work has attempted to analyze the factors that have affected the choice of ownership in China.[5]

Drawing on descriptive analysis based on the CWMS data from Hebei and Henan, the study finds that several factors are associated with the shift of tubewell ownership from collective to private. Most strikingly, factor endowments—especially water—are correlated with ownership changes (Table 4). Specifically, in villages in which water is scarce, tubewell ownership has evolved quickly (shown in Table 4 by comparison of private tubewells with water scarcity between 1990 and 2004). Although the patterns in the descriptive statistics do not prove causality, they are consistent with the idea that private tubewells may have emerged in response to north China's growing water scarcity.[6]

Government programs to encourage investment by individual farmers and village leaders also may have influenced the pattern of tubewell ownership (see data on policy intervention in Table 4). For example, officials have implemented two main policies (fiscal subsidies and loans) that affect tubewell ownership decisions. Not all actors in any given community, however, are eligible for these programs. While the subsidy programs mainly support the investment efforts of individual farmers, banks typically

[5] Of course, in some sense one of the fundamental reasons that ownership has changed over time is the ideological shift brought on by China's reform movement in the late 1970s and early 1980s. However, despite this shift in policy, collective ownership is seen to continue in some places (even with denovo tubewells); they are privatized in some places; new wells are invested in by the private sectors in still others. All of this variation occurs after the reforms.

[6] While it is not believed that one can draw inferences from descriptive tables on causality, the work in the Phillipines by Fujiie et al. (2005) show that water scarcity does lead to institutional changes in the water sector. In other work using data from China in both the surface water sector (Huang Q, Msangi S, Wang J, Huang J, Contract Water Management Reform and the Choice of Contractual Form in China, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing, unpublished, 2005) and the groundwater sector (Wang et al. 2005b), econometric analysis is used to show that causality can be determined. Specifically, it is shown that in areas that are facing declining reliability in deliveries in surface water and falling groundwater levels, there is an emergence of private individuals that contractually take over canals and/or contract in or invest in their own tubewells. The mechanism that is behind this, only speculated about, is typcially that private individuals have more of an incentive to conserve increasingly scarce resources and that as more investment is needed (because of falling groundwater levels or the need for more water-conserving canals), the private sector has an incentive to invest in order to be able to maintain or further increase the productivity of their farms.

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Table 4 Relationship between tubewell ownership and resource endowment and policy measures in Hebei and Henan Province, 1990–2004

Year	Share of private tubewells (%)	Water scarcity	Policy intervention		Village fiscal health–
		Groundwater level (m)	Villages receiving investment subsidies for water projects (%)	Villages receiving bank loans for water projects (%)	Per capita village real fiscal income (yuan)
1990	49	9	2	0	27
1995	60	11	9	2	28
2001	78	14	23	14	28
2004	81	20	12	7	15

Data source: Authors' surveys in 48 randomly selected villages in Hebei and Henan Province (CWMS)

target the special loans to village leaders. Because of the targeting rules of the two policies, the study expects that in areas that have had relatively large fiscal subsidy programs, there should have been more of a shift towards private ownership. Likewise, in those areas with an active bank loan program, the access to special investment funds of the village leadership council may be keeping the collective active in maintaining or expanding their tubewells.

Finally, the survey finds that the village's fiscal health also affects the privatization of tubewell ownership. With declining village fiscal income, the capacity for village leadership councils to invest in tubewells apparently has diminished. Data demonstrated that, between 1995 and 2004, there was a negative relationship between the share of private tubewells and village fiscal income (Table 4). When per capita village fiscal income declined (from 27 yuan per capita to 15 yuan per capita), the share of private tubewells increases.

Perhaps even more generally, the decline of village fiscal health (and rise in preference for private ownership) is closely related with rural reform in China, which may ultimately be responsible for triggering the rise of private tubewells. Before the rural reforms in the 1960s and 1970s, township governments and village leadership councils financed most tubewells. In most villages individual farmers at most only contributed their labor for tubewell construction. During this period, the village leadership council controlled all the cultivated land and was charged with allocating and managing the revenue from land. The fiscal capabilities of most villages were strong. Individual farmers were endowed with few resources and were not encouraged to pursue investment or engage in their own economic activities. For these reasons, most of the groundwater investments and water management activities were under the control of the village.

Since the rural reforms in the early 1980s, however, the situation has reversed. Most collective land was evenly distributed to individual households. Due to the reforms, the fiscal revenue position of most villages has declined, especially relative to that of the individual producer. More importantly, the policy constraints that originally limited private activities have gradually been relaxed. In fact, in recent years policy makers have often encouraged individual farmers to become engaged in the groundwater economy. Therefore, the rural reforms can be said not only to have created a new policy environment that made it possible for individual farmers to invest in tubewells, but also increased ability of individual farmers to participate in the investment of tubewells. In some cases, private investment is clearly substituting for the declining investment capacity of villages.

Impacts of tubewell ownership privatization

Tracking the precise impact of the rise of private tubewells on irrigated area, production and income is difficult for several reasons. It is difficult to separate out the effect of rising groundwater use from privatization because there are two ways that the rise of the private sector can play a role. First, there is a *new well effect*. In other words, there is a privatization effect that will increase the number of tubewells. Had there not been the private sector, there would have been less groundwater use and less impact on irrigated areas. In addition, the production and income impacts of this effect is potentially quite large—essentially the productivity and income difference between irrigated and non-irrigated farming (see Huang et al. 2005) for evidence for the sharp yield and revenue effect associated with increasing irrigated area). Secondly, there also is an *efficiency effect* that potentially can affect production and income. Conditional on having a tubewell, this effect is measured as the difference between production and income that arises when a tubewell is operated by a private individual rather than the collective.[7]

The effect on the groundwater level in farming areas also is difficult to isolate because there are different channels—

[7] The literature in the rest of world also raises another effect, the *crowding out effect*. Although privatization is often seen to lead to efficiency gains, there could be negative distributional effects. When the collective is in charge, it is possible that the criteria (and terms) by which water is distributed is different than when private individuals are making decisions based on a profit maximizing basis. Hence, it is possible that although efficiency rise, total yields and/or income could fall. Because of lack of information on this effect, it is not discussed here. The work of Zhang et al. (2005) and Wang et al. (The Evolution of China's Groundwater Governance: Productivity, Equity and the Environment, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, unpublished, 2005), however, suggests that there has not been a large negative distributional effect of privatization.

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sometimes offsetting—through which increased privatization can affect overdrafting. When trying to identify the effects on the water table it is first necessary to understand that true water use is going to rise in one of two main ways in northern China—firstly, by the increased evapotranspiration (ET) associated with the expansion of sown area or the change in the mix of the crops being cultivated (henceforth, the *ET effect*) or secondly, by increased flow of unused irrigated water into sinks or into rivers systems that flow into the sea (henceforth, the *sink effect*). Following the discussion in the previous paragraph, both the new well effect (especially) and efficiency effect (more indirectly) can affect sown area and lead to an increase in the ET effect.

There also is one more way that the groundwater level can fall without the expansion of sown area.[8] It is possible that by switching irrigation sources from surface water to groundwater, the reduction of water available to the farming area would lead to a fall (or an acceleration in the fall) of groundwater levels in the farming area. Assume for example, a farming district was being irrigated by a surface water system that originally drew its water from a reservoir. If instead the water was diverted to a city in some other region (that pumped its effluent into a river that could not be reused or went to the sea), and if the farmers in the farming district began to rely on groundwater, there could be a (new) fall in groundwater levels.[9] Henceforth, the study calls this the *Switching (from Surface Water to Groundwater) Effect*.

Ownership change, irrigated area and productivity

Although it is possible that the groundwater economy would have expanded as fast as it actually did had the private sector not been involved, it is hard to imagine it being so. In the NCWRS sample villages from throughout northern China in total the collective had only invested in and operated around 4000 tubewells between the time groundwater started being exploited and 2004. In contrast, the private sector invested in more than 4000 tubewells in the nine years between 1995 and 2004. In short, while it is impossible to know for certain, it seems likely that the rise in private tubewells has increased irrigated area (or at least kept it from deterioriating or growing less fast).

Assuming that the private sector was a driving force behind the rising number of tubewells, decomposing the rise in the cultivated area that new irrigation covers demonstrates that there is both a new well effect and a switching effect. The decomposition analysis divides the total rise in the area irrigated by tubewell into three components: a.) the rise in newly irrigated area in newly irrigated villages (that is villages that previously grew crops that were not irrigated); b.) the net expansion in irrigated area in villages that previously had irrigated area; and c.) the rise in irrigated area which replaced the irrigated area that originally was supplied by surface irrigation (also in villages that previously had irrigated area). According to the data, of the rise of area irrigated by tubewells (about 8,000 ha from 20725 ha in 1995 to 28542 ha in 2004), about 4,000 ha (approximately half) are in newly irrigated villages. This rise in irrigated area occurred in 46 newly irrigated villages (on average about 87 newly irrigated ha per village). There was also 667 ha of newly irrigated area from surface water.

The rest of the increased tubewell-supplied irrigated area occurred in the 219 villages that previously had irrigated area. In these villages, although the total expansion of area irrigated by tubewells was 3,000 ha, the net increase in irrigated area was only 2,000 ha. Data also suggest that there were at least two projects that increased surface water-supplied irrigated area by 333 ha. Hence, this means that there were 1,667 ha of newly expanded irrigated area from groundwater. Although it is almost certain that not all of the 5,667 ha (4,000 ha in newly irrigated villages and 1,667 ha in previously irrigated area) can truly be counted as a new well effect (the amount of irrigated area that would not have been irrigated had there not been private tubewells), at least a part (and probably a large part) of the 5,667 ha is due to the new well effect. The rest of the expanded tubewell-supplied irrigated area, by deduction, must be due to the switching effect. In the NCWRS sample villages (2,333 ha) the amount of area that was originally irrigated by surface area before being supplied by groundwater is equal to the difference between the rise in area supplied by tubewells in previously irrigated areas (4,000 ha) and the amount of the net increase in newly expanded tubewell-supplied irrigated area (1,667 ha). Although this is a large shift, there may not be much of a production or income effect, as long as the crop yields on this area did not change significantly (when producers switched from surface water to groundwater). According to Huang et al. (2005), while there is a big difference between non-irrigated crop yields and irrigated crop yields, there is much less difference between yields from cultivated area irrigated by surface water and yields from cultivated area irrigated by groundwater.

In fact, when examing the CWMS data, the relationship between ownership and crop yields is not clear. It is true that the descriptive data illustrate that crop yields increase over time as private tubewell ownership increases (compare share of private tubewells with crop yield in Table 5). There are, of course, many reasons (such as new technology) why yields may have risen. The correlation between tubewell ownership is less strong when examining the rates of increase of yields; crop yields rise much less rapidly than that of private tubewell ownership (Table 5).

In contrast, descriptive statistics indicate that with rising percentage of private tubewells, farmers increase their earnings sharply. When the share of private tubewells increased from 49 to 81% between 1990 and 2004, real

[8] If the long term weather patterns changed, there could also be an acceleration in the lowering of groundwater levels without an expansion of sown area. It is assumed that the duration of this study period is too short to have been influenced by such a fundamental set of effects.

[9] A similar effect would occur if the surface water canal system or reservoir became unusable and the water originally sent to the farming district stayed in the mountains (and either evaporated or went into a sink) or continued flowing in the river and flowed into the sea.

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Table 5 Relationship between tubewell ownership, and cropping patterns and yields in Hebei and Henan Province, 1990–2004

Year	Share of private tubewells	Share of sown area (%)				Crop yield (kg/ha)		Real farmer income[a] (yuan)
		Wheat	Maize	Cotton	Other cash crops	Wheat	Maize	
1990	49	44	27	6	5	4155	4650	815
1995	60	45	26	6	6	4515	5010	1211
2001	78	45	26	9	6	4890	5625	1831
2004	81	41	30	10	10	5295	5490	2261

Data source: Authors' surveys in 48 randomly selected villages in Hebei and Henan Province (CWMS)

[a]1990 price

farmer income also increased from 815 to 2261 yuan. While these strong positive results disappear in the multiple regression analysis, the coefficient on the variable relating the share of tubewells in a village to income is positive (although not significant). At the very least, however, there is not any net negative effect of privatization. In fact, there is not much evidence of a negative distribution effect. In other work by the authors (The Evolution of China's Groundwater Governance: Productivity, Equity and the Environment, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, unpublished, 2005), the rise of private tubewells has not increased the incidence of poverty (rather it is neutral). Hence, if there is an efficiency effect of private tubewell ownership (either positive or negative) on either yields or income, it is not strong enough to show up in either analysis described in this paper, or the work of others.

In summary, then, there is evidence in the new data (and in the work of others that support the findings of the work presented in this paper) that the rise of the private groundwater economy has had positive effects on crop yields and income in rural China between 1990 and 2004. If it can be assumed that at least some of the rise in groundwater is due to a new well effect, then the evolution of the groundwater economy has helped increase crop yields and incomes. If there are any negative distributional impacts, they are not strong enough to show up in the current data. In fact, to the extent that the emergence of private tubewells raises crop yields and agricultural income, according to work by Rozelle (1996) and Huang et al. (2005), any factor that increases the incomes of farmers will reduce inequality.

The emergence of private tubewells and the effects on the water table

According to our strategy of analysis, there are only a small number of ways that the expansion of the private groundwater economy may be affecting the water table. Following the same set of assumptions made above, one of the main effects of the emergence of private tubewells is due to the new well effect. In any area that the rise of groundwater use (from the increased area sown and increased intensity of production in newly irrigated areas, both of which will increase ET) is not being offset by an equal volume of recharge, groundwater levels will fall. In fact, in 78% of both the newly irrigated villages and in the previously irrigated villages that experienced newly expanded irrigated area, the groundwater level is falling. Hence, it appears as if at least one of the reasons for China's falling groundwater levels is that new tubewells are increasing sown area.

The water table may also have been affected by the switching effect. In fact, in villages in which the rise in tubewell-supplied area exceeds the rise in total irrigated area (implying that there was decrease in surface water irrigation), 65% of villages experienced a fall in groundwater level. Of these villages, 33% are falling faster than the average rate of fall. Unfortunately, this study was unable to tell from the data why it is that the surface water irrigated area fell (that is, whether it was due to the deterioration of the surface water system or the diversion of the water for other uses).

Significantly, according to the current analysis, with the exception of the new well and switching effects (discussed above), there are not many other ways that the rise of private tubewells affect the water table. For example, the current data show that when the share of private tubewells increased from 49 to 81% between 1990 and 2004, the share of sown area under wheat cultivation decreased by 3% (Table 5). At the same time, the share of areas under maize and cotton increased. Most importantly, the area devoted to other crops (mostly horticulture crops) rose by 50% (from 5% in 1990 to 10% in 2004).[10] Although descriptive statistics from the CWMS data also indicate that changes in tubewell ownership may have led to shifting cropping patterns, it is unclear how much of the change in cropping patterns is due to the rise of private tubewells. There certainly are many other factors that affect cropping patterns. In fact, when using multiple regression analysis, part, but not all, of the shifts in cropping patterns over time are associated with the rise of private tubewells. Wang et al. (2005a) suggest that it may be the greater efficiency of private tubewell owners that allows for the cultivation of more season-orientated crops (such as horticulture crops).

However, even if all of the observed shifts in cropping patterns were due to the rise of private tubewells, it is unclear if there would be much effect on the water table.

[10] To maintain focus in this paper only descriptive statistics are shown . Although it is impossible to infer causality from these on their own, in other work (Wang et al. 2005a,b) it is shown the these relationship hold up in multiple regression analysis using both the CWMS and the NCWRS data and, in fact, the correlations in the descriptive statistics can be interpreted as causal.

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According to technical manuals based on extensive experimentation in many different parts of China (Chen et al. 1995), there is really little difference in annual water use (mostly ET) for the major crops in the region. The differences between wheat, maize, cotton and horticulture crops are, on average, less than 10–20%. Hence, the overall effect of any cropping pattern shift must be small.

Likewise, the efficiency effect of the rise of private water use on the water table also appears to be small. In multiple regression analysis (reported in Wang et al. 2005b; Wang et al. The Evolution of China's Groundwater Governance: Productivity, Equity and the Environment, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, unpublished 2005), one of a series of equations examines the determinants associated with the lowering of groundwater levels. In the current analysis with the CWMS data (1990–2001), there is a small positive effect of the rise of private tubewells on the water table. In the analysis using the NCWRS, the effect is negative. However, in each case the magnitude of the effect is so small that it would account for at most only a small fraction of the new well and switching effect.

Concluding remarks

In this paper the study has sought to understand the privatization of tubewell ownership in northern China and its effect on irrigated area, productivity, income and the water table. The results show that since 1990 collective ownership of tubewells has largely been replaced by private ownership. In fact, private, as opposed to collective, tubewell ownership has become the dominant form of ownership in many regions.

The changes in ownership were found to be related to four, sometimes offsetting factors. First, changes in relative resource endowments, in particular the declining groundwater levels, encouraged a shift towards private ownership. The shift is consistent with the *induced innovation hypothesis* (as also is commonly found in other developing economies). According to this hypothesis, when facing a resource scarcity, agents in an economy will be innovated to save the scarce resource. Since as resources, such as groundwater, become more scarce, they also become more expensive, the private sector may emerge since it has more of an incentive to find ways to save the scarce resource. Second, fiscal subsidy programs that directly extend funding to individual farmers for tubewell investment give farmers the means to own/operate tubewells, thereby encouraging private tubewells. Third, and in contrast, targeted bank loan policies aimed mainly at village leadership councils for tubewell investment impede tubewell privatization and the expansion of denovo private tubewells. Finally, after rural reform in the early 1980s, it has become legal for individual farmers to dig tubewells; in addition, the investment capacity of village collectives has declined while the capacity of farmers has increased. Clearly though, the net effect of the four factors has been the expansion of private tubewells.

In terms of impacts on irrigated area, crop yield, income and the water table, although it is impossible to definitively measure the exact impact of the rise of private tubewells, with a set of plausible assumption, there appears to have been a significant impact. By far, the most important effect appears to be the new well effect. To the extent that the rise of private groundwater economy has aided the expansion of groundwater use for irrigation (in both new villages and previously irrigated villages), there would have been positive crop yield and income effects. There appears also to have been some positive effects resulting from the switching effect (crop yields and income would have gone down had tubewell-supplied irrigation not replaced the fall in surface water irrigation). Since both of these effects likely will have either increased sown area and cropping intensity (and, as such, ET), in this way the rise of private tubewells have contributed to the fall in the groundwater level. However, despite this the study has seen little impact of negative distribution and little negative efficiency effects of the rise of private tubewells.

Should measures be taken to slow the rise in groundwater use? If the answer is yes, clearly this means that actions also must be taken to slow the rise of private tubewells. According to Wang et al. (2005b), however, the regulatory capacity of the government to stop the drilling of new tubewells is quite weak. New efforts would have to be made to increase the ability to implement policies and regulation in groundwater-use areas. Above all, if new and effective regulations are put in place, the government needs to understand that this will come at the cost of crop yields and income. There clearly is a tradeoff in that as (private sector-driven) groundwater-use rises, groundwater levels fall, but incomes and crop yields rise. What is not clear is how the government should respond. If decisions are made to arrest the fall in groundwater levels and if farmer income is not to be undermined, there needs to be a set of complementary policies that restricts groundwater use by the private sector but delivers subsidies to them to offset the negative income effects.

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References

Barker R, Molle F (2002) Perspectives on Asian Irrigation, Paper Presented at the Conference on Asian Irrigation in Transition-Responding to the Challenges Ahead, 22–23 April 2002 Workshop, Asian Institute of Technology, Bangkok, Thailand

China National Bureau of Statistics (2002) China Statistical Yearbook. China Statistic Publishing House, Beijing

Chen Y, Guo G, Wang G, Kang S, Luo H and Zhang D (1995) Water Demand and Irrigation of Major Crops in China. China Water Resources and Hydropower Publishing House, Beijing

 DOI 10.1007/s10040-005-0482-1

Fujiie M, Hayami Y and Kikuchi M (2005) The conditions of collective action for local commons management: the case of irrigation in the Philippines. Agricultural Economics 33(2):179–190

Hebei Hydrological Bureau and Water Environmental Monitor Center (1999) Hebei Water Resources Assessment. Hebei Water Resources Bureau, Shijiazhang

Huang Q, Rozelle S, Hu D, Huang J and Wang J (2004) Making the Pumps that Prime South Asia's Groundwater Green Revolution: The Role of China's Pump and Engine Industry, Working Paper, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing

Huang Q, Dawe D, Rozelle S, Huang J and Wang J (2005) Irrigation, poverty, inequality in rural China. Australian Journal of Agricultural Resource Economics 49(2):159–176

Lohmar B, Wang J, Rozelle S, Huang J, Dawe D (2003) China's agricultural water policy reforms: increasing investment, resolving conflicts and revising incentives. Agriculture Information Bulletin #782, Economic Research Service, USDA

Li H and Rozelle S (2004) Privatization with a tail: the buyout price and performance of privatized firms in rural China. Journal of Development Economics 75:1–26

Meinzen-Dick R (1996) Groundwater markets in Pakistan: Participation and Productivity. Research Reports 105, International Food Policy Research Institute, Washington, DC

Ministry of Water Resources (2000) China Water Resources Bulletin. Available from URL: http://www.chinawater.net.cn/cwsnet/gazette-new.asp [In Chinese, accessed on 10 January 2002]

Nickum J (1988) All is not wells in north China: irrigation in Yucheng county. In: O'Mara GT (ed) Efficiency in Irrigation. World Bank: Washington, DC, 87–94

Otsuka K (1995) Land Tenure and Forest Resource Management in Sumatra: Analysis Issuers and Research Policy for Extensive Survey, (MP 11) IFPRI :Washington, DC

Rozelle S (1996) Stagnation without equity: patterns of growth and inequality in China's Rural Economy. The China Journal 35:63–92

Shah T (1993) Groundwater Markets and Irrigation Development: Political Economy and Practical Policy. Bombay, India: Oxford University Press

Tang S (1991) Institutional arrangements and the management of common-pool resources. Public Administration Review 51(1):42–51

Uphoff N (1986) Local Institutional Development: An Analytical Sourcebook with Cases. West Hartford, CT: Kumarian Press

Wang S (2004) Recent Trends in Poverty in PRC. ADB Institute, Sharing Development Knowledge about Asia and the Pacific http://www.adbi.org/discussion-paper/2004/01/04/83.poverty.targeting/recent.trends.in.poverty.in.prc/ [accessed on 28 January 2005]

Wang J, Huang J, Blank A, Huang Q and Rozelle S (2005a) The development, challenges and management of groundwater in rural China. In: Giordano M, Shah T (ed) Groundwater in Developing World Agriculture: Past, Present and Options for a Sustainable Future, International Water Management Institute

Wang J, Huang J and Rozelle S (2005b) Evolution of tubewell ownership and production in the North China Plain. Australian Journal of Agricultural and Resource Economics 49(2):177–195

White A (1995) Conceptual Framework: Performance and Evolution of Property Rights and Collective Action, (MP 11), IFPRI: Washington, DC

Xu Z (2001) Studying on increasing water use efficiency. Journal of China Water Resources 455:25–26

Zhang L, Wang J, Huang J and Rozelle S (2005) Development and determinants of groundwater markets in North China. Journal of South China Agricultural University (Social Science Edition) 4(3):1–6

 DOI 10.1007/s10040-005-0482-1