Chapter 14
Assessment of the Development of Groundwater Market in Rural China

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Abstract Using field survey data collected by the authors, this chapter first describes groundwater markets in northern China that have been developing rapidly in the past two decades. Groundwater markets in the area are informal, localized and mostly unregulated. There is little price discrimination, and institutional characteristics tend to be similar in both high- and low-income villages. The privatization of tubewells is one of the most important driving forces encouraging the development of groundwater markets. Increasing water and land scarcity are also major determinants. The chapter also explores the impacts of the emergence of the groundwater markets on agricultural production – including crop water use and crop yields – and farmer income in northern China. Results indicate farmers that buy water from groundwater markets use less water than those that have their own tubewells. However yields of water buyers are not negatively affected. This is probably because water buyers exert more efforts to improve water use efficiency. Results also show that other things held constant, the crop incomes of water buyers are not statistically different from those of well owners. The chapter also finds that groundwater markets in northern China are not monopolistic, supporting the notion that they offer poor rural households affordable access to irrigation water.

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14.1 Introduction

Groundwater resources are playing an increasingly important role in the economy of northern China. In 2011, on average, 35.5 % of the total water supply (industrial, residential and agricultural sectors) came from groundwater (Ministry of Water Resources of China 2011). Agriculture relies even more heavily on groundwater. As public investment in canal systems waned and deliveries became more unreliable, farmers in northern China began to rely more on small irrigation systems fed by groundwater. The rapid expansion of groundwater irrigation has stimulated the growth of agriculture in northern China (Huang et al. 2006). In the North China Water Resource Survey (NCWRS) survey (described below) sample villages, in 2004, with the exception of rice, at least 70 % of the area sown to grains and other staple crops were irrigated by groundwater (e.g., 72 % of wheat and 70 % of maize, Wang et al. 2007). Groundwater also irrigates most cash crops (e.g., 70 % of cotton, 62 % of oil seed crops and 67 % of the vegetables).

In most rural areas in northern China, central and regional governments have little control over groundwater use. China's National Water Law (China 2002), which was revised in 2002, stipulates that all property rights over groundwater resources belong to the national government, including the right to use, sell and/or charge for water. In practice, however, villages that lie above the aquifers have the de facto rights to groundwater resources. Unlike the US, water rights are not associated with land ownership or historic use. Often they are associated with the ownership of wells. Despite the plethora of laws and policy measures created by government officials, there has been a lack of enforcement (Wang et al. 2007). One of the reasons is the difficulty in regulating millions of small, water using farmers. Another reason is historic neglect. The administration unit that is in charge of groundwater management at the ministerial level is still relatively small. There are far fewer officials working in this division than in other divisions, such as flood control, surface water management or water transfer projects. Moreover, unlike the case of surface water management (Lohmar et al. 2003), there has been no effort to bring the management of aquifers that span jurisdictional boundaries (e.g., counties or provinces) under the control of a single authority that can regulate and coordinate among users in different parts of the aquifer. As a result, few regulations stipulated by upper level government have been implemented at the village level. For example, despite the nearly universal regulation that requires the use of a permit for drilling a well, less than 10 % of the sample well owners in the 2004 NCWRS survey obtained one before drilling. Only 5 % of sample villages had any consideration for well spacing.

With the lack of control from upper level governments, groundwater use is organized and managed at the village level. Before the rural reforms in the 1980s, wells in almost all rural villages were collectively owned and financed primarily by collective retained earnings and additional funding from township governments. Village leaders were largely responsible for arranging for the water resource bureau-run well drilling companies to sink tubewells. Pumps, before the reform all came from either the water resource bureau pump supply company or the state-run local agricultural inputs corporation. As the curator of collective assets, village leaders made decisions on all aspects of water management: when and where to sink the wells, how many wells to sink, and, importantly, how much water to extract during each season. Village leaders often hired a well operator to pump water and deliver to households under their instruction. In most villages individual farmers at most contributed their labor for tubewell construction and maintenance.

Changes brought on by the economic reforms forced local village governments to be fiscally more independent. Many villages, particularly those without lucrative nonagricultural enterprises, eventually faced serious fiscal shortfalls and were unable to invest in agriculture (Lohmar et al. 2003). In addition, due to the fall of the groundwater level and lack of maintenance of pumps, engines and other equipment, a number of collective tubewells became inoperable. As the collective's ability to invest in maintaining existing wells or replacing pumps or sinking new wells declined, farmers began to take its place and the ownership of wells began to shift from collective ownership to private ownership (Wang et al. 2005). This transition took place in the macro environment in which policy makers started to gradually relax the constraints on private activities. In particular, the economic reform has shifted income and control rights of land from the collective to the individual household. The survey conducted by Wang (2000) in Hebei Province showed that in the early 1980s collective ownership accounted for 93 % of all tubewells but diminished throughout the late 1980s and 1990s. During this period the share of private tubewells increased from 7 to 64 %. This is consistent with findings from the NCWRS survey (described below, Wang et al. 2007). In 1995, 58 % of wells in groundwater-using villages were still under collective ownership. By 2004, the share of privately owned wells rose to 70 %, shifting a large part of groundwater management into the hands of private individuals. The shift of tubewell ownership is the result of the establishment of new tubewells rather than ownership transfers of collective tubewells although the absolute number of collective tubewells has declined. The number of private wells sunk by farmers (either an individual farmer or a group of farmers jointly) has increased significantly.

As tubewells have come under the control of private individuals, access to groundwater for those farmers who do not own wells has become a new issue. Groundwater markets have not always existed. In the 1970s and 1980s, when most wells were owned and operated by the collective, in almost all villages simple rules governed water allocations. Under these rules households in the village received an equal share of the total water allocation that was based on the land size. It should be noted that unlike other countries, such as India, land is relatively equally allocated among households in rural China both in terms of land size and soil quality (Benjamin and Brandt 2002). The egalitarian nature of the land distribution provided some rationale for the simple rule of equal water allocation.

Concurrent with the trend of increasing privatization of wells is the development of groundwater markets. Following a pattern similar to that observed in South Asia (Shah 1993, 2009), groundwater markets have begun to emerge in which owners of tubewells sell groundwater irrigation services, mostly to fellow villagers within the village and in some cases to farmers from outside the village. When village leaders (the collective) provided water to villagers, it was done under non-market conditions because any irrigation fees collected went into the village's collective fund, not as compensations to village leaders. In fact, in some villages, the collective provided water free or at a subsidized rate.

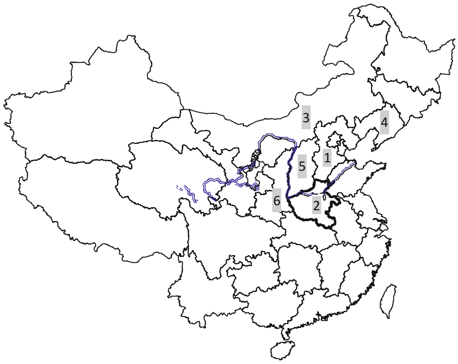
The changes in well management have the potential for affecting the rural economy and the nation's water resources. The increased access to groundwater enabled by groundwater markets clearly has the potential to boost agricultural productivity. However, as tubewells have begun to be operated by private individuals and sunk to deeper levels, concern has also arisen that farmers do not have an equal access to groundwater (Meinzen-Dick 1996). Farmers that are buyers in groundwater markets may be forced to use less water because they may have to pay more for water than well owners or farmers serviced by the collective wells. As a consequence, yields and crop income of those farmers may be negatively affected. In addition, policy makers and scholars also debate the question of whether the prevalence of groundwater markets accelerates the decline of water levels in aquifers. Despite the importance of these issues, only a few papers have examined groundwater markets in rural China (e.g., Wang et al. 2005; Zhang et al. 2008, 2010; Huang et al. 2013). This chapter summarizes findings in the previous studies that address these important issues. The focus is on agricultural use of groundwater in northern China. This chapter begins by documenting the development of groundwater markets in northern China and describing the characteristics of groundwater markets. The next section identifies the factors that have led to this development. The third section analyzes the impact of groundwater markets on agricultural productivity, rural incomes and groundwater resources. The final section draws conclusions and discusses policy implications.[1]

14.2 Groundwater Markets in Northern China

Analysis in this chapter is based on two field surveys the authors have conducted. The first survey, the China Water Institutions and Management survey (CWIM) tracks 48 randomly selected villages in Hebei and Henan provinces (Fig. 14.1).

[1]Most materials in this chapter are adapted from the following two articles: Zhang, L., Wang, J., Huang, J., Rozelle, S., 2008, Groundwater Markets in China: A Glimpse into Progress. World Development 36 (4): 706–726.

Zhang, L., Wang, J., Huang, J., Huang, Q., Rozelle, S., 2010, Access to groundwater and agricultural production in China, 97:1609–1616.



CWIM sample provinces:

1. Hebei; 2. Henan;

NCWRS sample provinces:

1. Hebei; 2. Henan; 3. Inner Mongolia;

4. Liaoning; 5. Shanxi; 6. Shaanxi.

Fig. 14.1 Study areas in northern China

The CWIM sample area covers two of the nine major river basins in China. Hebei province covers most of the Hai River Basin and surrounds Beijing. Henan province is located in the middle reaches of the Yellow River Basin. A stratified random sampling strategy was used. The strata are geographic locations, which were correlated with the extent of water scarcity. In Hebei province, one county was randomly selected from each of the three regions: the coastal belt, the most water scarce area of China; the inland belt, an area with relatively abundant water resources since it is next to the mountains in the western part of Hebei province; and the region between the coast and mountains. In Henan counties were randomly selected from each stratum that includes irrigation districts with varying distances from the Yellow River. Locations further away from the river are typically associated with increasing water scarcity. After the sample counties were selected, we then randomly selected 48 villages from these counties. In the CWIM survey enumerators interviewed three sets of respondents: village leaders, randomly-selected households (between 1 and 4 households per village) and randomly-selected well managers. Separate survey questionnaires were designed and used for each set of respondents. The household level data collected in the CWIM survey enable us to analyze the impacts of groundwater market on the crop income of households and plot level water use.

The second survey, the North China Water Resource Survey (NCWRS) covers six randomly chosen provinces: Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi provinces (Fig. 14.1). Similar to the CWIM survey, a stratified random sampling strategy is used. Counties in each province were divided into four water scarcity categories: very scarce, somewhat scarce, normal and mountain/desert. Two townships within each county and four villages within each township were then randomly selected. In total, the survey team visited 50 counties, 100 townships and 401 villages. In the NCWRS survey we only interviewed village leaders due to limitations in time and budget. A more comprehensive version of the CWIM survey village leader questionnaire was used. Data were collected on most variables for 2 years, 2004 and 1995.

14.3 Development and Characteristics of Groundwater Markets

Although almost nonexistent before 1980, by 1995, groundwater markets were present in 9 % of the NCWRS villages that used groundwater and had private wells, defined as wells belonged to farmers (not the collective). Groundwater markets spread at a much faster rate over the next 10 years. By 2004, tubewell operators in 44 % of the sample villages were selling water. At the same time when groundwater markets were expanding spatially, in villages that had groundwater markets, markets become more active. In 1995 water was sold from only 5 % of tubewells; by 2004, however, this number increased to 18 %. In 2004, the average number of tubewells per village was about 75 and water was sold from between 13 and 14 wells in each village. In addition, using the CWIM survey data that contain detailed well-level information, we found that groundwater market activities were dominating the tubewell pumping activities of those farmers-cum-tubewell owners that were selling water. About 80 % of water pumped from private wells was sold in the groundwater market in 1995 and 77 % in 2004. The slight drop from 80 % in 1995 to 77 % in 2004 may be due to the increase in the number of wells, which increased the total available supply of groundwater in the market and at the same time reduced the demand for water because more farmers were pumping from their own wells. Between 1995 and 2004, both the number of wells selling water and the total number of wells increased. In the 68 sample villages that were in the NCWRS, the number of wells selling water increased from 75 in 1995 to 342 in 2004; at the same time, the total number of wells also increased from 1,472 to 1,967.

Although groundwater markets in northern China started later than those in South Asia, they do share some common features. First, almost all groundwater markets in China are *informal*. According to Shah (1993), a water market is informal when transactions between water-selling and water-buying households are done without legal sanction. In other words, farmers buy and sell water without a contract and their oral commitments cannot be adjudicated in a court of law. According to the data, there were zero written contracts covering water sales among participants in the groundwater markets in northern China. Payment is enforced by social norm because sellers and buyers often reside in the same village and often know each other personally. In addition, sellers can refuse to sell water to a buyer in the future if the buyer has not paid for some or all water received in the past. The informal nature is consistent with the general environment in China where the rule of law is still weak. It significantly reduces the transaction cost (such as legal fees to draw up a formal contract and the cost of enforcing the contract) which participants in the markets would have to incur otherwise. This may be one of the reasons why groundwater markets were able to grow at a fast rate in north China.

Second, groundwater markets in northern China are almost always localized. According to Shah (1993), the localized nature of water markets is almost universal due to the constraints on the infrastructure required to transport water. In the survey data in China, water transactions also are mostly limited to households in the same village. In fact, only 6 % of water-selling tubewell owners (and a smaller share of the volume of water that they pump) sell water to farmers in neighboring villages.

Third, groundwater markets in northern China are largely unregulated. In Shah (1993) the word unregulated means the government exercises no direct influence on the functioning of the market. According to NCWRS survey data, fewer than 25 % of villages have any formal regulations in writings about any aspect of groundwater markets (e.g., a price ceiling or the amount pumped). The regulations appear to be largely unenforced. During the field work and interviews with tubewell owners, enumerators almost never encountered a case in which the tubewell owner was constrained by a government regulation; village leaders and tubewell operators were typically unaware that there was any attempt by upper level officials to influence the functioning of water buying and selling.

Fourth, groundwater markets in northern China are largely impersonal. Based on our interviews with village leaders, we found that within villages, only 7 % of water selling tubewell owners charge different prices. In addition, in our survey of the tubewell owners, not one reported that they charged different prices for different types of buyers. Shah (1993) also finds water-selling households in some villages of India do not distinguish among various buyers in terms of price at which they sell water and the quality of service provided. Price discrimination, however, has been observed in other parts of India (Pant 2004) and in other countries such as Pakistan (Jacoby et al. 2004).

Groundwater markets in China do differ in some aspects from those in other countries. In northern China, water sold in groundwater markets is almost always paid for on a cash basis. In India water buyers often provide labor or a share of crop harvest in exchange for water (Shah 2000). The difference in the payment method may be rooted in the difference in land tenure arrangements. In China the ownership of cultivated land belongs to village collectives. Since the household responsibility system was implemented in rural China in the early 1980s which allowed rural households to manage agricultural production on their own initiatives and keep the profits after tax, cultivated land has been allocated relatively evenly to each household within a village. So every farmer in the village has some land he/she can use for agricultural production, although they have no land ownership. However, in South Asia, land allocation is unequal and land ownership varies. There are land lords as well as landless tenants. Tenants often pay the rent to land owners either with labor or a share of their harvest (i.e., through a sharecropping contract). So it is not surprising that water-buying households pay for water in similar ways. Another important difference between groundwater markets in China and South Asia is the way in which electricity is priced. This, too, may have a major impact on the way groundwater markets function. For instance, in many Indian states, electricity is priced on a flat rate basis. In China, however, electricity is priced on a per kwh basis and at market rates (no subsidy). Electricity meters are installed at almost all wells that use electric pumps. Since the pumping cost (and consequently the price of water) is closely related to the depth to water, it reflects mostly the scarcity value of water. Furthermore, in India rural electrification is poor and, hence, many farmers depend on diesel pumps. This may create a configuration of groundwater markets somewhat different from those where there are electric pumps.

14.4 Determinants of Groundwater Markets

Zhang et al. (2008) use econometric analysis to identify the factors that explain why some villages have groundwater markets and others do not. They run two regressions, each using one indicator of groundwater development as the dependent variable: the share of tubewells selling water and the share of water sold. In both regressions, in addition to variables that measure water and land scarcity, a set of control variables is included (Table 14.1). Three policy variables are used. First, fiscal subsidies for tubewells equals one if there was a program of fiscal investment in the village that targeted tubewell construction and zero otherwise. This government program, run by the local Bureau of Water Resources, is primarily targeted at individuals. Second, a similar variable, bank loans for tubewells, is included to control for whether or not there was a loan program through China's banks that gave preferential access to low interest rate loans for investing in tubewells. Unlike the fiscal subsidy program most bank loan programs target local villages and village leaders; the loans are supposed to be used on collective wells. A third variable, well-drilling regulations, controls for the presence of local regulations that would, ceteris paribus, slow down the construction of tubewells. In addition to the policy variables, several other variables are also included. A dummy variable is used, which equals one if the village had adopted technology such as surface (called white dragons in rural China) or underground pipe networks. It is thought that if the cost of delivering water from the tubewell to the field is lower, water markets will emerge more readily. Village income per capita is included to measure the village's socio-economic conditions. In the regression with the share of tubewells selling water as the dependent variable, the share of private tubewells is included as a control variable. In the regression with the share of water sold as the dependent variable, the control variable is a dummy variable that equals one if the tubewell is owned by an individual farmer and zero if the tubewell is owned by a group of farmers (share-holding wells).

The analysis reveals four factors that have fostered water market development (Table 14.1). First, the change of tubewell ownership from collective to non-collective induces the development of groundwater markets. All other things held constant (e.g., village's socio-economic condition, use of water conveyance technology and the policy environment), when the share of the non-collective tubewells in a village increases, the share of tubewells selling water increases. Although causality cannot be inferred, this result shows the correlation between privatization and the rise of groundwater markets. One explanation is that in some villages, private tubewells have risen in response to less service available from collective tubewells either because those wells ran dry or were not maintained. Therefore, in these villages, it would be necessary for farmers to gain access to water from sales from private tubewells.

Second, the development of groundwater markets is highly related to water resource scarcity. There is a clear indication of increasing water scarcity over time. Here water scarcity is measured by the depth to water in wells. In the NCWRS sample villages that have private wells, depth to water in wells fell from 28 m in

Table 14.1 Tobit regression of the determinants of development of markets in China

	Dependent variable: share of tubewells selling water				Share of water sold
	(1)	(2)	(3)	(4)	
Tubewell ownership					
Share of private tubewells	0.183	0.286	0.180	0.286	
	(3.86)***	(7.70)***	(3.83)***	(7.40)***	
Dummy of individual tubewell					0.389
					(4.33)***
Water and land scarcity					
Log of groundwater table	0.003	0.006	0.003	0.006	
	(3.82)***	(5.06)***	(3.81)***	(4.96)***	
Log of groundwater table in 1995					0.008
					(2.01)**
Log of per capita cultivated land	−0.900	−1.036	−0.909	−1.036	−4.745
	(2.39)**	(3.21)***	(2.40)**	(3.10)***	(3.50)***
Policy interventions					
Dummy of fiscal subsidies for tubewell investment	0.051		0.041		−0.121
	(0.46)		(0.38)		−1.58
Dummy of bank loans for tubewell investment	0.065		0.066		0.484
	(0.59)		(0.60)		(3.02)***
Dummy of well-drilling permission regulation	0.116		0.117		0.045
	(3.09)***		(3.08)***		−0.46
Other control variables					
Dummy of adopting water delivery pipes	−0.025	0.008			−0.093
	(0.64)	(0.23)			−0.94
Per capita net income of farmers	−0.000	−0.000	−0.000	−0.000	0.000
	(0.18)	(0.88)	(0.24)	(0.85)	(1.94)*
Constant	−4.257	−3.853	−4.204	−3.918	−2.943
	(3.68)***	(4.74)***	(3.66)***	(4.76)***	(3.34)***
Observations	136	136	136	136	50
Chi-square	35.19	96.41	35.30	94.29	46.37

Data source: Data in the model "share of tubewells selling water" come from authors' survey in 68 randomly selected villages in four provinces (Hebei, Henan, Shanxi and Shaanxi) in 2 years (1995 and 2004) of NCWRS. Data in the model "share of water sold" come from authors' survey in 50 randomly selected tubewells in two provinces (Hebei and Henan) of CWIM. We do not use data from all of the sample villages of the two surveys since the information in the table is conditioned on villages that use groundwater to irrigate and that have private tubewells

[a]Coefficients represent marginal effects; absolute value of z statistics in parentheses

[b]* significant at 10 %; ** significant at 5 %; *** significant at 1 %

1995 to 38 m in 2004. The data show a positive and strong correlation between the depth to water in wells and the amount of groundwater market activity measured as either the share of tubewell selling water or the share of water sold. Regression analysis also reveals the same relationship: in areas in which the depth to water in wells is greater, farmers' demand for water from groundwater markets is higher (relative to obtaining water from one's own well). One explanation is that when the depth to water in wells is greater, the cost of sinking a tubewell is higher, which could keep some farmers from investing in their own tubewells even though they have a high demand for irrigation services. Alternatively (although mainly in a relative sense), it could be that the greater the depth to water in wells, the larger is the size of the optimal tubewell/pump set. In villages with larger tubewells/pump sets, other factors (including size of land holding) held constant, there is less of a need for all farmers to have their own tubewells. In either case, there is some empirical evidence that groundwater markets develop more quickly in villages with scarce water resources.

Third, the data also lend some support to a positive relationship between land pressure and the extent of groundwater markets. Land pressure has increased. Between 1995 and 2004 the average size of land holding per capita for the sample villages fell from 0.12 to 0.10 ha. Regression analysis show that with the decrease of per capita land resources, the share of tubewells selling water has increased and the average tubewell operator sells a greater share of water pumped from his/her tubewell. This result still holds when land pressure is measured by cultivated land per household (instead of per capita). So when the average land holding in a village shrinks, there is more of a tendency for its tubewell owners to sell water. This is probably because with a smaller farm size, households demand less water and are thus less likely to sink their own tubewells. This, however, does not necessarily imply that only small households are buying water. In China, there was not much difference in the size of the land that was allocated to farmers *within the same village* (Benjamin and Brandt 2002). Therefore, the positive relationship between land pressure and groundwater markets activities is largely driven by inter-village differences. This means that it is in villages that have mostly small households that have more sales, as opposed to villages with mostly large households. This distinguishes the market in China from those in other countries, particularly those in South Asia.

Finally, if the tubewell is owned by an individual (a single household), a higher share of water is sold, compared with shareholding tubewells. Since the demand by the individual farm household for water from its own well is more likely to be less than that of all the members of the shareholding tubewell, a positive relationship would be expected, due to the excess capacity available for sale.

Most of these findings are consistent with international experience. For example, Shah (1993) descriptively shows that the availability of water resources, the scale of irrigation technology and the extent of land fragmentation are correlated with the rise of groundwater markets. Strosser and Meinzen-Dick (1994) argue that the depth of groundwater table and the population density of a community are the important factors affecting groundwater markets.

14.5 Impacts of Groundwater Markets

This section examines the impacts of groundwater markets on groundwater resources, agricultural productivity and crop income. The household level data from the CWIM data are used. Plot or household is used as the unit of analysis. Wheat is the major crop grown on most plots during the winter season (planted during the previous October and harvested in June) in Hebei and Henan provinces. In our sample, about 94 % of the sample plots (or 97.6 % in terms of sown area) only grew wheat in the winter season. Only a small percentage of the sown area was allocated to other crops including beans, legume and cash crops such as oil crops and vegetables. After wheat is harvested, either maize or cotton (competing summer crops) is grown in the summer season (planted in June and harvested in October). In both Hebei and Henan provinces, the rotation of first wheat and then maize or cotton is the most common cropping pattern. In Henan province, rice is another major crop grown in the summer season. Most cash crops are also grown in the summer season. Wheat production relies more heavily on irrigation than other crops in the region. This is because the growing season for summer season crops (June to October) coincide with the rainy season in the region while that of wheat does not. For example, in years with abundant rainfall, corn could potentially be 100 % rainfed. There is little or no overlap between the irrigation of wheat and that of summer season crops since those crops are usually planted after wheat has been harvested. Since wheat is the major crop that relies on irrigation in the region, we only use the data on the plots that grew wheat in 2004. By doing so, we hold the type of crop constant and also amass the largest number of observations.

Consistent with the findings from the NCWRS data, the CWIM data show that farmers in the North China Plain have three ways to access groundwater. About 47 % of households were still using groundwater from collective tubewells in 2004. The remaining 53 % of households are pumping water from private wells. Among them, about 30 % of households irrigate their crops from their own tubewells. The remaining 23 % buy water through markets.

14.5.1 Impact on Water Use

The CWIM data show that compared with other ways to access groundwater, farmers who gain access through groundwater markets use less water to produce wheat. In 2004, farmers who buy groundwater to irrigate wheat use 9 % less water than farmers who use water from their own tubewells (3,241 versus 3,571 m^3 per hectare). The level of water use by water buyers is also 11 % lower than that by farmers relying on water from collective tubewells (3,660 m^3).

The results remain when we restrict the comparison to be only within villages. In about 40 % of villages, farmers can access groundwater in more than one way. In some villages, one group of farmers irrigates wheat from their own tubewells and another group irrigates their wheat with purchased groundwater. In some cases, a single household has two plots that are in separate locations and the household has sunk a well next to one plot but needs to buy water to irrigate wheat grown on the other plot. When comparing the two groups of farmers or two types of plots, those farmers getting irrigation from their own tubewells use 12 % more than farmers buying water from markets. In addition, in other sample villages some farmers gain access to irrigation from collective tubewells while others purchase their irrigation from groundwater markets. Those farmers in the villages that use water from collective tubewells use 35 % more than farmers that buy water from groundwater markets. When regression analysis is used that controls for the characteristics of villages, households and plots, the difference in water use between farmers that use water from their own wells and farmers that rely on collective wells disappears (Table 14.2). In the regression analysis, the key variables are the two dummy variables that measure the various ways of accessing groundwater: the first equals one if farmers irrigate their plots by buying water; the second equals one if farmers irrigate their plots by pumping water from collective tubewells. The base group is those farmers that use water from their own tubewells.[2]

Importantly, regression results still show that water use falls for farmers that buy water from groundwater markets compared with those that have their own tubewells (Table 14.2). So why is it that farmers that buy water use less water? One reason may be that farmers that purchase water pay more for their water. If so, they would have an incentive to reduce water use. Compared with farmers that pump from their own tubewells or depend on water delivered from collective tubewells, farmers that buy water have higher outlays for their water. The cost of water buyers pay to irrigate wheat is 0.39 yuan per cubic meter, which is more than two times the cost of pumping water well owners incur.[3] When the comparison is restricted to be within villages, the results are the same: water buyers pay more than other farmers that do not depend on groundwater markets for irrigation. Because of this, it is reasonable to expect that farmers that purchase their water on groundwater markets will use water differently than those farmers that have their own tubewells.

The empirical results discussed here are also relevant to the investigation of the impact of groundwater markets and more generally the privatization of wells on

[2]Other control variables are also included. The first group of variables measures the village's production environment such as the share of irrigated area serviced by groundwater and the degree of water scarcity in the village. The second group of variables measures household characteristics such as age and education of the household head. Finally, we also control for plot characteristics such as plot size, soil type and the distance of the plot from home. Access to groundwater, however, suffers from potential endogeneity, because there may be some unobserved factors that affect both water use and the way farmers access groundwater (e.g., water yields of the aquifers). The Instrumental Variable (IV) estimation is used in order to control for the potential endogeneity of access to groundwater. The instrumental variables are two policy interventions variables that measure the way in which policy markers have attempted to intervene in China's groundwater markets. In our field work and during interactions with officials in the local Bureaus of Water Resources, officials told us that they believed that these government programs were done on a basis that is not related to the water use in the village; village leaders and farmers almost never were aware that they could influence these programs. Personal relationships (between officials with control over subsidy/loan programs and village leaders) often was one of the most cited basis for granting a subsidy or a loan to a village leader or farmers (Luo and Kelly 2004). Therefore, the instrumental variables, fiscal subsidies and bank loans for tubewells, are most likely to be exogenous. There is no reason to believe that they have any independent effect on water use except through their influence on the way in which farmers gain access to groundwater.

[3]Yuan is the unit of currency used in China. One dollar was about eight yuan in 2004 and about seven yuan in 2008.

Table 14.2 Impact of groundwater markets on crop water use, crop yield and farmer income

	Log of water use per hectare for wheat	Log of wheat yield per hectare	Crop income per capita	Total income per capita
Buying water from private tubewell (1 = yes; 0 = no)	−0.340 (1.65)*		84.249 (0.05)	−718.512 (0.34)
Using water from collective tubewell (1 = yes; 0 = no)	−0.424 (0.97)		2,305.948 (1.51)	861.595 (0.44)
Production inputs				
Log of water use per hectare		0.022 (0.44)		
Log of labor use per hectare		−0.066 (1.37)		
Log of fertilizer use per hectare		0.134 (2.49)**		
Log of value of other inputs per hectare		0.105 (2.40)**		
Production environment				
Share of village irrigated area serviced by groundwater	−0.315 (1.18)	0.148 (1.22)	437.095 (0.74)	169.110 (0.23)
Village water scarcity indicator variable	0.155 (1.82)*	0.014 (0.30)	−102.536 (0.34)	−215.973 (0.56)
Household characteristics				
Age of household head	0.051 (0.83)	−0.002 (0.11)	22.576 (0.31)	54.391 (0.60)
Age of household head, squared	−0.001 (0.95)	0.000 (0.25)	−0.053 (0.07)	−0.384 (0.37)
Education of household head	−0.014 (0.67)	0.003 (0.31)	−59.787 (1.19)	42.633 (0.67)
Area of plot	−1.088 (1.91)*	−0.371 (1.66)*		
Number of plots per household	−0.003 (0.17)			
Population of household	0.063 (1.74)*			
Arable area per capita of household			9,412.560 (3.69)***	6,123.917 (1.89)*
Plot characteristics				
Loam soil	−0.004 (0.03)	0.040 (0.70)		
Clay soil	0.069 (0.61)	0.115 (2.13)**		
Distance to home	−0.163 (1.26)	−0.097 (1.91)*		

(continued)

Table 14.2 (continued)

	Log of water use per hectare for wheat	Log of wheat yield per hectare	Crop income per capita	Total income per capita
Water saving technology				
Share of surface or underground channel	−0.275 (2.26)**			
Flood irrigation (1 = yes; 2 = no)	−0.108 (0.98)			
Production shocks				
Yield reduction due to production shocks		−0.015 (10.44)***		
County dummy	–	–		
Constant	7.932 (6.12)***	6.860 (9.20)***	−2,017.856 (1.19)	−644.721 (0.30)
Observations	120	140	200	200
R^2	0.37	0.61	0.10	0.09

Absolute value of z statistics in parentheses; * significant at 10 %; ** significant at 5 %; *** significant at 1 %

China's groundwater resources. Partly because the shift to private well management during 1990s coincided with the rapid decline of water levels in aquifers, some scholars have blamed private well management for the accelerated decline in groundwater levels in northern China (Zhang and Zhao 2003). When wells are managed by the collective, the authority associated with village leaders entails the presence of some governance structure in the groundwater sector, which is often missing in most groundwater economies including India (which is now the largest groundwater economy worldwide, Shah 2009). Village leaders, as the custodian of the village's asset including water resources, may have incentive to conserve groundwater for future use. In contrast, when wells are controlled by farmers, the incentive of a well owner to conserve water may be limited. Given the typical large number of wells in groundwater-using villages, the incentive diminishes rapidly as the number of competitors increases. Even if the well owner wants to regulate water use, he is just one person in a village of water users, and does not have the same authority as village leaders and thus would be less effective in influencing his fellow villager's water use. As a result, it is entirely plausible that unregulated pumping by well owners could result in the tragedy of the commons.

The empirical results discussed above, however, show that the difference in water use between farmers that depend on collective wells and farmers that depend on private wells (either as buyers or sellers) are not statistically significant. In other words, there is little difference between collective well management and private well management in terms of their effects on groundwater. When trying to explain this result, Huang et al. (2013) shows that the hydrology of the aquifers plays a key role. If water in an aquifer is accessible not only to the village above the aquifer but also to neighboring villages, the water level in one village may be affected by the pumping of neighboring villages (or nearby cities) and vice versa. If this is the case, then the aquifers underlying the different villages are connected. In villages using connected aquifers, instead of being assured that water not used in this period is available in future periods, they now need to worry about what their neighboring villages will do because water left in the aquifer this period may be pumped away by them and thus no longer available in future periods. In such cases even village leaders do not have incentive to conserve water. Huang et al. (2013) test this hypothesis by including a dummy variable that equals one if a plot is in a connected village in the regression with plot level water use as the dependent variable. The regression results show that only in villages that are hydrologically isolated from other villages do we observe a higher level of water use by farmers that depend on private wells for irrigation. Farmers that pump from private wells use 70 % more water than those pump from collective wells and the difference is statistically significant at 1 %. Given that a large share of the villages (more than 60 %) are connected, it is not surprising to find no difference between collective well management and private well management.

14.5.2 Impact on Agricultural Productivity and Crop Income

The previous section shows that farmers that purchase their water on groundwater markets use less water than farmers that have their own tubewells. As a result, crop yields and income of water buyers may also be negatively affected. Data show that if farmers irrigate wheat with water purchased from groundwater markets, the average yield is 4,843 kg/ha, which is slightly lower (by 1 %) than that of well owners. A simple *t* test shows that the difference is not statistically significant. Compared with farmers that depend on collective tubewells, the average wheat yield of water buyers is lower by 8 %. The result is not significant (at the 5 % level) either. The results are still the same when comparison is restricted to farmers within the same village: wheat yields of water buyers are lower but the difference is not statistically significant.

The results of regression analysis (Table 14.2, second column) are also consistent with the descriptive analysis: although water use per hectare falls for farmers that buy water from groundwater markets, yields do not fall significantly.[4] Thus, even though those who buy water from groundwater markets use less water, wheat yields are not negatively affected. While we are not able to prove why empirically, observations during our field work suggest that this is because those that buy water

[4]Wheat yield is regressed on water use per hectare and other production inputs including the amount of labor per hectare measured in man days, fertilizer measured as expenditure per hectare and expenditures on other inputs such as harvesting services. The regression also includes the same set of variables as in the regression on water use above to control for village, household and plot characteristics. We also added a variable that represents production shocks, measured as the farmer-estimated percentage reduction in yields due to floods, droughts or other negative events. The impact of groundwater market on crop yield is measured through its impact on water use.

may be working harder at not wasting water. During our discussions with farmers, we are repeatedly told that because they pay more for their water, farmers that buy water from private tubewell owners pay strict attention to when the water is being applied.

The descriptive analysis indicates that groundwater markets may have a negative effect on the income of farmers that buy water. Per capita crop income for water buyers is 902 yuan, which is only 61 % of that of tubewell owners (1,482 yuan) and 77 % of that of farmers getting irrigation from collective tubewells (1,168 yuan). However, when regression analysis is used, the estimated coefficient on the groundwater market variable is not statistically significant in either the crop income or the total income equations.[5] This means that when other factors are held constant, compared with tubewell owners and farmers that buy water from collectively managed wells, the income of those that buy water from groundwater markets is not lower.

14.5.3 Do Groundwater Markets Help the Poor?

As groundwater markets become increasingly important, it is necessary to understand whether groundwater markets are helping or hurting the poor, and how they affect rural China's income gap. Elsewhere in the world, research has shown that groundwater markets can be equity enhancing. For example, Meinzen-Dick (1996) shows that groundwater markets in Pakistan has improved the equity of groundwater use by making water available to small landowners, tenants and younger households, the group of farmers that are least likely to own tubewells. This may also be the case in China. The results discussed above show that both rich and poor farmers participate in the groundwater market. The data indicate that groundwater markets benefit farmers that are small, less educated, and older. The per capita land area of water-buying households is 0.13 ha, slightly smaller than that of water-selling households (0.15 ha) but the difference is not statistically significant. The average years of schooling of the head of water-buying households is 5.5 while that of water-selling households is 6.3 and the difference is statistically significant. The average age of household head of water-buying households is higher by 2.4 years (50 versus 47.6) and the difference is statistically significant.

Whether groundwater markets benefit the poor is likely related to the structure of the markets (that is, whether they are monopolistic or competitive). The poor should be able to benefit more when markets are competitive than when faced with a single

[5]In the regression on crop income or total income, control variables are similar to those in the regression on water use with two differences. Variables that measure plot characteristics are excluded since this is a household level regression. Total land size and household size are replaced by their ratio: arable land per capita. The same instrumental variable strategy is used to address the endogeneity problem.

seller. To measure the degree of competition, following the work of Lerner (1970), Shah (1993) argues that the ratio of water price to total variable cost can be used as a fairly good indicator of the level of monopoly power. Following this approach, we calculate the ratio of water price to total variable cost to examine the structure of groundwater markets in China. Our data yields a "competitive" ratio of 2.2, ranging from 1.2 to 3.3. More than 70 % of tubewells have ratios lower than 2.5. Hence, if the low ratio of water price to total variable cost does, in fact, measure competition, there is evidence that groundwater markets in China are relatively competitive. In contrast, in some areas in India such as eastern Uttar Pradesh, this ratio is as high as 3.6 (Kumar 2009).

Another way to assess the degree of competitiveness of China's groundwater markets is by comparing within-village price variations to between-village variations. Since groundwater markets are localized and most transactions are among farmers in a single village, if markets were competitive, we would expect prices to vary mostly between villages, not within villages. Indeed, this is what we observe in the data. For example, in one village the price of water from one tubewell is more than 3.4 times that from one tubewell in another village. However, within any of our villages, the highest price difference is only 50 %. In 75 % of the sample villages, water price differences among tubewells selling water within villages are much smaller than that. This is consistent with the findings of other researchers. After controlling for the influence of other factors, Kajisa and Sakurai (2003) found that the variation of water prices in their sample in Madhya Pradesh of India mainly comes from regional differences, leading them to the conclusion that groundwater markets are not monopolistic. In our sample villages that have both collective tubewells and private tubewells selling water, we found that water price of collective tubewell is only slight lower than in the private groundwater markets. On average, the difference in the price of water between collective tubewells and private tubewells is less than 15 %. Also, we found no statistically significant difference in the price of water between private tubewells owned by individual farmers and those owned by a group of farmers (shareholding tubewells).

Our data provided two additional pieces of evidence that support the non-monopolistic nature of groundwater markets. First, we looked at profits from selling water. With our data, we were able to estimate both the fixed and variable costs of pumping and selling water. Accordingly, our results demonstrate that (even when we do not consider the value of family labor that is used to pump and sell water), profits are generally small.

Second, we also looked at the number of well operators selling water and at water delivery conditions. Shah (2000) suggests that when wells are sunk in a fairly dense manner, and when there are lined conveyance structures in a village, there is less of a probability that a single seller will have monopoly power and that the price of water will be relatively more competitive. Using this approach with our survey data, we find that in almost all villages, there are many tubewell operators selling water, not just one. Furthermore, the adoption rate of efficiency-enhancing conveyance technologies (surface plastic pipes or hoses) by farmers in groundwater irrigation regions of northern China is high, at over 70 %, partly because these technologies are not expensive. The adoption of surface pipes greatly increases the ability of farmers to choose the tubewells from which they want to buy water. Based on these analyses, it seems that groundwater markets in northern China almost certainly are not monopolistic, supporting the notion that they offer poor rural households affordable access to irrigation water.

14.6 Concluding Remarks

Our results provide strong evidence that groundwater markets in northern China have developed in terms of both their breadth (the share of villages in which there are groundwater market activity) and depth (the share of water which the average water-selling tubewell owner sells to others on a market basis). Groundwater markets in northern China are informal, localized and mostly unregulated. There is little price discrimination, and institutional characteristics tend to be similar in both high- and low-income villages.

While much of the results are suggestive that groundwater markets are largely self- organizing and unregulated, there does appear to be a role for the state. The findings show that when the government facilitates individuals' and shareholding groups' access to capital, and when they are not subject to local regulations, there is a greater level of groundwater market activity.

In terms of the effect of groundwater markets on access to water for low-income households, our research shows that poor households have been involved in both the supply and demand side of the markets, which is somewhat different from what has been observed in other parts of the world where groundwater markets have emerged. This may be because well-functioning, competitive markets that will expand access to resources for the poor require a relatively unregulated market environment, as well as agents that have access to a minimum amount of land and capital resources. In the case of China, almost all households have land and the government has instituted programs offering loans and grants to those wanting to sink a well. In addition, the incomes of most farmers were already high enough to allow some farmers to gain access to enough capital for investment (and to sufficient liquidity) that they were able to afford to buy water when it was provided in a competitive market environment. When groundwater markets emerge in such an environment, buyers and sellers can both benefit, and overall access to water can raise production levels and the welfare of all participants. In places where land and capital resources are less equitably distributed, this may not occur.

Further evidence that groundwater markets expand irrigation access to the poor comes from our results showing that households that buy water from groundwater markets are poorer than households that sell water on the market. Our research shows that farmers who purchase their water on the market pay more on a per cubic meter basis than farmers who either have their own tubewell or have access to water from collectively owned wells. They also use less water. However, crop yields do not fall, nor is there any measurable negative effect on income. Since Huang et al. (2006) have shown that irrigation has a positive impact on agricultural production and rural incomes, and we have shown above that the households accessing water through groundwater markets are able to maintain agricultural production equal to that of households that access water through other means, it follows that groundwater markets have a positive impact on the incomes of those who participate. Moreover, since low-income households are the primary purchasers, groundwater markets can be said to decrease regional income inequality through their disproportionate positive impact on low-income households.

Our research also has important policy implications. They indicate that farmers respond to incentives: when farmers have to pay more for water, they take measures allowing themselves to save water while maintaining crop yields. Groundwater markets thus represent a simple way to increase water efficiency without materially hurting either production or incomes. As water in China becomes more scarce, and water efficiency needs to be increased, allowing the emergence of groundwater markets may be an efficient way to provide irrigation services.

Assuming that farmers who rely on groundwater markets are unable to access water elsewhere, groundwater markets should lead to an increase in groundwater use and an expansion of irrigated area. While this accrues financial benefits to the individual farmers, it raises concerns as to the long-run sustainability of such a scheme. Despite the relatively efficient water use of farmers who purchase water on groundwater markets, their increased water usage may still be contributing to a fall in the groundwater table. If this is the case, should groundwater markets be abolished? We say no. Instead, water pricing policies should be promoted to control the drawdown of the water table. This would encourage greater water efficiency across the entire irrigating population – instead of simply among those who have no other access to irrigation water – while continuing to afford poorer farmers the access to groundwater that would otherwise be unavailable to them. Thus, the pro-poor benefits that come from increased access to irrigation would be maintained, while the potential negative impact on the water table would be at least partially offset by increased water savings among all users. Of course, policy makers will also benefit from studies that examine groundwater institutions and rules of water allocation which can assist in explaining the impacts of groundwater markets (Aarnoudse et al. 2012; Bluemling et al. 2010).

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