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Groundwater Entrepreneurs in China: Selling Water to Meet the Demand for Water

Lijuan Zhang*, Jinxia Wang and Jikun Huang,
Center for Chinese Agricultural Policy
Institute of Geographical Sciences and Natural Resources Research
Chinese Academy of Sciences

Scott Rozelle
Department of Agricultural and Resource Economics,
University of California, Davis

Lijuan Zhang is research assistant, Jinxia Wang is associate professor and Jikun Huang is professor and director in the Center for Chinese Agricultural Policy (CCAP), Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China. Scott Rozelle is professor, Department of Agricultural and Resource Economics, University of California, Davis.

*Corresponding author:

Lijuan Zhang
Center for Chinese Agricultural Policy
Chinese Academy of Sciences
Jia, No.11, Datun Rd, Anwai
Beijing 100101, China
Phone: (8610) 64889841 Fax: (8610) 64856533 Email:zhanglj.ccap@igsnrr.ac.cn

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SUMMARY

The overall goal of our paper is to better understand the development of groundwater markets in northern China. In particular, we focus on the factors that determine the development of groundwater markets in our attempt to explain their ‘breadth’ and ‘depth.’ Based on a survey of 24 randomly sampled villages and 50 randomly sampled tubewells in two provinces (Hebei and Henan Province) in 2001 and a field survey of 68 randomly sampled villages in 4 provinces (Hebei, Henan, Shanxi, and Shaanxi) of northern China in 2004, our results show that groundwater markets in northern China have emerged and are developing rapidly. Our results show that groundwater markets in northern China are informal and localized, developing in a number of ways that make them appear somewhat similar to markets that are found in South Asia. However, groundwater markets in northern China also differ from those in South Asia in other ways—water sellers discriminate in pricing and they almost always work on a spot-market, cash bases (that is, there are no share or labor sharing arrangements as often found in South Asia). Econometric results show that the privatization of tubewells is one of the most important driving factors that encourage the development of groundwater markets. Increasing water and land scarcity are also major determinants that induce the development of groundwater markets.

Key words: Groundwater markets; characteristics; determinants; equity; northern China; Asia

JEL Classification Codes: O53; Q15; Q25

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In recent years groundwater has begun to play an increasingly important role in irrigation in China, especially in northern China where per capita water availability is less than one-twentieth of the world average (Liu and He, 1996). Although surface water dominated China's irrigation development in the 1950s and 1960s, since the end of 1960s groundwater gradually has become the primary source of irrigation water. According to official statistics, between 1965 and 2003 the number of tubewells increased from 0.2 million to 4.7 million (Ministry of Water Resources and Nanjing Water Institute, 2004; Ministry of Water Resources, 2003). Nearly all of the tubewells (95 percent) are in northern China. Today, these tubewells provide about 68 percent of the total irrigation water in northern China (Wang et al., 2005a).

The rise of groundwater in China not only fueled an expansion of sown area and rising production (Huang et al., 2005), as the reliance on groundwater has increased China's groundwater economy has become characterized by a growing water crisis (Wang et al., 2005a). In many parts of China the water table has begun to fall. As a result, there has been a concomitant rise in the cost of sinking a tubewell. In parts of the North China Plain the shallow water table has been dropping at a rate of more than one meter per year (Ministry of Water Resources, 2002). The deep water table has fallen faster, declining at a rate of more than two meters per year in some areas (Wang et al., 2005b). The cost of sinking and operating a tubewell has at least doubled in many parts of northern China (Huang et al, 2005).

During the 1990s at the same time the groundwater table was falling, the ownership of tubewells also has begun to evolve. Before the rural reforms in the 1980s, most

tubewells were owned and operated by the collective. For a variety of reasons, including the decline in the strength of the collective and the increased freedom of individuals to invest in their own farms, soon after the economic reforms began in the early 1980s the ownership of China's tubewell began to shift sharply from collective to private (Wang et al., 2005b). The number of private tubewells increased from almost nothing in the 1970s to nearly 40 percent by 1990. The shift to private tubewell ownership continued during the 1990s and beyond. For example, in 1995 collective ownership accounted for 58 percent of tubewells in the average groundwater using village in northern China (Wang et al., 2005a). By 2004 private tubewells rose to 70 percent.

While the rise of private tubewells has been shown to lead to more efficient use of water, higher levels of irrigated area and more complex cropping systems (Wang et al., 2005b and Wang et al., 2005c), it has also made *access to irrigation water* an increasingly important issue. During the Socialist era (1950s through the 1970s) when local leaders were in charge of allocating groundwater in almost all villages, the equitable distribution of groundwater was not an issue. However, as tubewells have been installed and begun to be operated by private individuals, and as tubewells have begun to be sunk to deeper levels (making the real price of water rise), concern has arisen that not all farmers may have equal access to groundwater (Meinzen-Dick, 1996). It is possible that the farmers that have access to the capital are the ones that are more likely to sink and manage tubewells. It also is possible that because of this, these better endowed farmers have much better access to water than those without tubewells. If so, it is possible that part of the gains from

increased efficiency that accrues from the rise of private tubewell ownership is being offset by rising inequities in the distribution of water and the associated gains.

The rise of private tubewells, however, does not have to lead to inequities if groundwater markets emerge and function well. While little has been written on groundwater markets in China, outside of China groundwater markets have long existed and recently have attracted the attention of researchers. For example, markets in groundwater have are found in many parts of South Asia. In 1975 a World Bank study in Pakistan reported nearly 30 percent of tubewell owners sold part of their pumpage to other farmers (Shah, 2000). In the early 1990s Pant (1991) found that 86 percent of the households in eastern Uttar Pradesh purchased water for irrigation; in central and western Uttar Pradesh 65 percent of farm households purchased water. More recently studies in Pakistan by Strosser and Meinzen-Dick (1994) and Meinzen-Dick (1996) have found groundwater markets pervasive. While the analysis of many issues are complicated and the findings of many studies controversial (meaning more study is needed on the management of groundwater markets), the South Asian experience has shown that groundwater markets in many places have provided opportunities for the farmers without tubewells to get access to water (Shah, 1993; Strosser and Meinzen-Dick, 1994; Mukherji, 2004; Sharma, 2004).

Despite the observations by field workers regarding the similarities between the rise of groundwater markets in China and those of South Asia, almost no empirical studies have been done on the development of China's groundwater markets. In fact, our search of the literature has found that there is almost no reference in any work on groundwater markets

in either Chinese or English. Despite the absence of research, policy makers and scholars have begun to raise a series of questions. How prevalent are groundwater markets in northern China? More specifically, what is the proportion of the tubewells that participate in selling water? How much of their water do they sell? What are the characteristics of groundwater markets in northern China? Who are the buyers? Finally, why is that we observe water markets in some villages but not in others? In other words, what are the determinants of groundwater markets in northern China and what are their effects on the equity of access to water?

The overall goal of our paper is to answer these questions in order to develop a better understanding of the development of groundwater markets in northern China. To do so, we focus our efforts on getting the data right and providing a profile of groundwater markets and their determinants in northern China. To meet this goal, we have four specific objectives. First, we describe the evolution of groundwater markets in northern China. Second, we explore their characteristics. In doing so, we compare China's groundwater markets to those that have emerged in South Asia. Third, we measure the determinants of groundwater markets in northern China and try to understand why they have emerged in some villages but not in others. Finally, we seek to understand what types of farmers are selling water and what types of farmers are buying water in an effort to understand the equity implications of emerging groundwater markets.

While there is no generally accepted definition of groundwater markets in the literature, in our paper groundwater markets are defined as localized, village-level arrangements through which owners of tubewells sell pump irrigation services to other

farmers of the village (i.e., they sell water to other farmers from their wells for use on crops). In our paper we are only going to examine “private” water markets. In other words, we examine the nature of groundwater markets that are being driven by individuals and groups of individuals that sink tubewells. In making such a definition, we are assuming that when village leaders (the collective) provide water to villagers, this is being done under *non-market* conditions and are not included as a part of groundwater market transactions.

In order to pursue our objectives, the paper is divided into six sections. The first section introduces the data. In the second section we use the data to compare the characteristics of groundwater markets in Northern China with those in South Asia. The third and fourth sections descriptively analyze the determinants of the development of groundwater markets and present the results of our multivariate analysis on the determinants of groundwater markets. The fifth section discusses whether or not groundwater markets are tending to help or hurt the poor. The final section concludes.

Data

Our analysis is based on data that we collected as part of two recent surveys specifically designed to examine irrigation practices and agricultural water management issues in northern China.¹ The first survey, the China Water Institutions and Management survey (CWIM), was conducted in September 2004. Enumerators conducted surveys of village leaders in 24 villages having non-collective tubewells and 50 non-collective tubewells owners in the selected 24 villages in Hebei and Henan Provinces. Located in

the North China Plain, the two provinces face serious water shortages and have the highest extent of groundwater irrigation (about 78 percent of irrigated area is from groundwater). Villages in Hebei were chosen from counties near the coast, near the mountains and in the central region between the mountains and the coast. In Henan villages were chosen from counties bordering the Yellow River and from counties in irrigation districts varying distances from the Yellow River. The most prominent feature of this survey is that we were able to collect information on water allocation and water sales from tubewell owners and managers—both those that sold water and those that did not.

The study team also conducted a second survey, the North China Water Resource Survey (NCWRS), in December 2004 and January 2005. This survey of village leaders from 400 regionally-representative villages in Inner Mongolia, Hebei, Henan, Liaoning, Shaanxi and Shanxi provinces used an extended version of the community level village instrument of the CWIM survey. Using a stratified random sampling strategy for the purpose of generating a sample representative of northern China, counties in each of our regionally representative sample provinces were sorted into one of four water scarcity categories: very scarce, somewhat scarce, normal and mountainous/desert. Two townships within each county and four villages within each township also were randomly selected. In total the data collection team visited 6 provinces, 60 counties, 126 townships and 448 villages. Although the information on water sales in the NCWRS is somewhat less rich than the CWIM survey (given that we only surveyed village leaders and not tubewell owners directly), by using the NCWRS survey we are able to generate representative point estimates of the prevalence of water markets across northern China.

The scopes of two surveys were quite broad. Each of the survey questionnaires included more than 10 sections. Among the sections, there were those that focused on the village's resource base (both the scarcity of water and the amount of cultivated land), the evolution of the ownership of tubewells, the village's basic socio-economic conditions and government policies and regulations.ⁱⁱ

In addition, there was a section that focused specifically on groundwater markets. We asked village leaders if there are tubewell owners that sell water to farm households that do not own tubewells. The survey also tabulated the number of tubewells in a village from which water was sold by its owner. Detailed information was elicited on the water sales activities of each village's typical tubewell, including estimates of the total volume of water withdrawn, the volume water that was sold and information on how *water-buying households* paid for the water that they bought from the *water-selling farmers*. A series of questions were asked of the village leaders about government regulations governing the price of water sold from tubewells. Finally, several questions focused on asking water-selling households (or *tubewell owners*) if they sold water to farmers inside or outside of the village.ⁱⁱⁱ

Both surveys were designed in ways that allowed the construction of data with an intertemporal component. The surveys collected data on most of the variables for more than two years. For example, the CWIM survey covered four periods: 1990, 1995, 2001 and 2004. The NCWRS survey covered 1995 and 2004.

Groundwater Markets with Chinese Characteristics

In this section we measure the degree of the development of groundwater markets in terms of both breadth and depth as well as describe their characteristics. The *breadth* of groundwater markets is measured by two indicators. One indicator is the share of villages that have any degree of groundwater market activity. The second indicator is the share of tubewells from which the tubewell owner is selling water to water-buying households. *Depth* is measured by the “share of the volume of water” sold to water-buying households that is pumped from tubewells that are selling water.

When using breadth indicators, groundwater markets have developed quickly in northern China. According to the NCWRS survey, in 1995 groundwater markets had emerged in only 9 percent of the sample villages (Table 1, column 1, row 1). However, by 2004 there were groundwater markets in 44 percent of the villages (column 2). During the same period, the share of tubewells from which owners sold water also increased. In 1995 water was sold from only 5 percent of tubewells; by 2004, however, this number increased to 18 percent (row 2). In addition, when using indicators of the depth of groundwater markets, the CWIM survey shows that by 2004, groundwater market activities were dominating the tubewell pumping activities of those farmers-cum-tubewell owners that were selling water (row 3).

Although there has been a lot more attention given to the study of groundwater markets in those countries in South Asia, our data show that China is catching up quickly. For example, a number of studies suggest that groundwater markets have become quite pervasive in Pakistan (Strosser and Meinzen-Dick, 1994; Meinzen-Dick, 1996). These

studies indicate that 30 to 60 percent of tubewell owners in Pakistan sell water. In India and other neighboring countries Shah (2000) shows that when tubewell owners sell water, they sell from 40 to 90 percent of the volume of water that they pump. Hence, while these numbers may not be exactly comparable, if we assume our estimates are correct (that is, water is being sold from 44 percent of tubewells in northern China; and when water-selling households sell water, they are selling 77 percent of the water from their tubewells), the development of groundwater markets in northern China are becoming close to those observed elsewhere in the world.

Characteristics of Groundwater Markets in Northern China

Although groundwater markets in northern China have evolved more recently, there are at least three characteristics in which it appears as if groundwater markets in northern China share with those in South Asia. First, almost all groundwater markets in both places 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 our data, there were zero written contracts covering water sales among agents in northern China; the same is true according to the literature from India.

Second, groundwater markets in both northern China and South Asia are almost always *localized*. According to Shah (1993), the localized nature of water markets is almost universal. In our data in China, water transactions also are mostly limited to water-selling and water-buying households that live and work in the same village. In fact,

we found that only 6 percent of water-selling tubewells (and a smaller share of the volume of water) sell water to farmers in other villages.

Finally, groundwater markets in both northern China and South Asia are largely *unregulated*. In Shah (1993) unregulated means the government exercises no direct influence on the functioning of the market. Shah's work finds little evidence of any intervention by any level of government in India. Based on the NCWRS survey data, in less than 25 percent of villages there were any formal regulations on the books about any aspect of groundwater markets (e.g., a price ceiling on the amount that a water-selling household can charge). Although somewhat higher than the case of India, in our field work and interactions with tubewell owners, we almost have never encountered a case in which the tubewell owner was constrained by a government regulation; village leaders and tubewell operators almost never were aware that there was any attempt by upper level officials to influence the functioning of water selling and buying.

While there are a number of similarities, it appears as if the different environments within which groundwater markets have evolved in northern China and South Asia have produced at least two differences in the nature of groundwater markets. First, Shah (1993) suggests that transactions between water-buying and water-selling households are typically *impersonal*. In India this means that water-selling households usually do not distinguish among various buyers in terms of price at which they sell water and the quality of service provided. In contrast, in the case of northern China groundwater markets are not fully impersonal. According to our 2004 NCWRS survey, 73 percent of water-selling tubewell owners charge different prices for different types of buyers. For example, a tubewell

owner might charge his relative one price, his neighbor another and a person from the next village another. If water is being sold from a shareholding tubewell, in many cases members of the shareholding team pay a different price for water than those that are not members.

Second, the *patterns of payment* of groundwater markets are different. In South Asia, water-buying households often provide labor or a share of their crop's harvest in exchange for water (Shah, 2000). In northern China, however, water sold in groundwater markets is almost always paid for on a cash basis.

Groundwater Markets, Tubewell Ownership and Resource Scarcity

In the small number of papers internationally that have sought to understand the determinants of groundwater markets, a number of factors arise consistently and can be used as a basis for generating hypotheses that we can test using our data from northern China. 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) set up a theoretical framework that posits (among other factors) the depth of the groundwater table and the population density of a community are important factors affecting groundwater markets. In other words, the observations of the researchers working on South Asia's groundwater markets suggest that groundwater markets are arising at least in part in response to the nature of the technology needed for sinking a well and the degree of resource scarcity—both that for land and water. If these observations and conjectures are

picking up more general relationships, then based on them we can generate a set of testable hypotheses: When the cost of sinking a well rises (either due to the falling groundwater table or the relative competitiveness of larger tubewells/pump sets) or when the attractiveness of sinking a well at a given cost declines (due to the fact that a farmer may have an increasingly small parcel of land that is not able to utilize the entire command area of a tubewell investment), groundwater markets can be expected to emerge.

According to descriptive statistics based on our data from northern China, we find there is empirical evidence for the hypotheses. For example, our data indicate that the development of groundwater markets is related with water resource scarcity (Tables 2). When the water table falls in the NCWRS sample villages over time (from 28 to 38 meters—column 2), the share of tubewells from which water is being sold is higher (column 1). When we divide the tubewells in the sample by the share of tubewells from which water is sold into four groups, there is a positive correlation between the amount of groundwater activity and level of the groundwater table (column 1, rows 3 to 6).^{iv} Likewise, when we divide the tubewells in the sample by the share of water sold in three groups, there also is a positive relationship between the amount of groundwater activity and level of the groundwater table (Table 3, columns 1 and 4). One explanation of these trends is that when the groundwater table is lower, the cost of sinking a tubewell is higher, which could keep some farmers from investing in their own tubewell even though they have a high demand for irrigation services. Alternatively (although mainly in a relative sense), it could be that the lower the groundwater table, the larger is the size of the optimal

tubewell/pump set. In villages with larger tubewells/pump sets, other factors (including land size) held constant, there is less of a need for all farmers to have their own tubewell.

Likewise, our data provides similar support for the hypotheses when looking at the relationship between groundwater activity and land scarcity (Table 2, columns 1 and 3). Between 1995 and 2004 the average size of land per capita for the sample villages fell from 0.12 to 0.10 hectares—rows 1 and 2). Coupled with the observed rise in the share of tubewells that are selling water, the descriptive data are consistent with the idea that when farm size gets smaller, households have less of a need to invest in their own tubewells. As a result, this could be one reason behind the rise in groundwater markets. The same trends appear when grouping observations either by the share of tubewells from which water is sold (rows 3 to 6) or by share of water sold (Table 3, columns 1 and 5).

Trips to the field and discussions with local officials and water users, as well as our data, also raise the prospect of one factor unique to China that may be behind the emergence of groundwater markets our sample. According to our data, the private ownership of tubewells is correlated strongly with the development of groundwater markets. Groundwater market activity is higher as the share of private wells has risen over time (from 50 to 81 percent—Table 2, columns 1 and 4, rows 1 and 2). Likewise, when our observations are group according to the water sales activity of the tubewells, the share of private wells in 2004 also rises sharply (from 68 to 100 percent—rows 3 to 6). Specifically, when the share of individual tubewells increases, the share of water sold is higher (Table 3, columns 1 and 2). Interviews with village leaders and tubewell owners and managers revealed that the main force driving this correlation appears to be the

incentives that private tubewell owners have to produce earnings from their tubewell investments. Hence, in studies of China, we also have an additional testable hypothesis that arises from descriptive statistics and observations in the field: Groundwater market activities rise as the share of private wells in a village increases.

Determinants of Groundwater Markets—Multivariate Analysis

In this section we seek to test more rigorously the determinants of groundwater markets. We are interested in identifying the factors that explain why some villages have groundwater markets and others do not; this analysis is needed because the findings will help us better understand the forces that are creating the swell in groundwater market activity. This is important since it may help us predict as China's villages confront the rising economic and environmental pressures of the nation's development process (e.g., forces, such as, the steady shift towards private ownership of productive assets; and increasing resource scarcity), whether or not institutions will emerge that will allow farm households to gain access to water, one of the most critical resources that they need for production. To analyze the determinants of groundwater markets, in the first part of this section, we introduce the methodology. In the next part, we report the results.

Methodology

Based on the descriptive analysis above and work on groundwater markets in other countries, we propose the following econometric model to analyze the determinants of the *breadth of groundwater markets*:

$$T_{jt} = \alpha + \beta O_{jt} + \gamma W_{jt} + \delta L_{jt} + \phi Z_{jt} + \varepsilon_{jt} . \quad (1)$$

In equation (1), T_{jt} represents the share of tubewells selling water in village j in year t .

The variables on the right hand side of equation (1) are those that explain differences in the breadth of groundwater markets (or the share of tubewells that sell water) among village and over time. The first variable, O_{jt} , represents the change of tubewell ownership and is measured as the share of private tubewells in village j . The two variables, W_{jt} and L_{jt} , measure the resource endowments of the village (both its water and land resources) and are included to identify if increasing resource scarcity (or cost of using the resource) helps induce the development of groundwater markets. Specifically, the water resources variable (W_{jt}) is measured as the level of groundwater table. The degree of land scarcity (L_{jt}) is measured as cultivated land per capita.

In equation (1) we also include a set of control variables. The first set of control variables includes three policy variables which are included to assess the effects of policy on the development of groundwater markets. The first variable, *fiscal subsidies for tubewells*, is a dummy variable equal to 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. A similar variable, *bank loans for tubewells*, is included to control for whether or not there was a program through China's banks that gives preferential access to low interest rate loans for investing in tubewells. Unlike the fiscal subsidy program most bank loan programs target local villages and leaders; the loans typically are supposed to be used to be invested in more collective wells. A final variable, *well-drilling regulations*, controls for the presence of local regulations that would, *ceteris paribus*, slow down the construction of

tubewells. Although there is no explicit policy to regulate collective or private tubewells, without the support of government, it is likely that such regulations, if present, would have a greater effect on slowing down investment in private tubewells. Our hypotheses are that any government program that encourages (discourages) private tubewells relative to collective wells will encourage (discourage) the development of groundwater markets.

In explaining the development of the breadth of groundwater markets, we also include the adoption of irrigation water conveyance technologies in the village as a way to control for the cost and efficiency of delivering water from the tubewell to the field. This variable is measured as a dummy variable, equaling one if the village had adopted conveyance-inducing technology, such as, surface (white dragons) or underground pipe networks. It is thought that if the conveyance of water is easier (and more efficient), water markets will emerge more readily. Finally, we also control for several other factors. For example, *village income per capita* is included as a control for the village's socio-economic condition. The symbols α , β , γ , δ and ϕ are parameters to be estimated and ε_j is the error term.

In order to analyze the determinants of development of the *depth of groundwater markets*, we specify the following econometric model:

$$M_j = \alpha + \beta O_j + \gamma W_j + \delta L_j + \phi Z_j + \varepsilon_j \quad (2)$$

where M_j represents the share of water sold for tubewell j . While the basic structure of equation (2) is the same as equation (1), because of the nature of the dependent variable (and differences in the sample—the breadth of water markets analysis uses village-level data; and the depth of water markets analysis uses tubewell-level data), the specification is

slightly modified. The first variable, O_j , represents the *ownership of tubewell j*, if the tubewell is owned by an individual (a single family), it equals to 1; otherwise, the tubewell is owned by group of individuals and equals to 0. Since the demand by the individual farm household for water from its own well is almost by definition less than the members of the shareholding group, we would expect the sign on the coefficient of the ownership variable to be positive (since there would be more of the excess capacity available for sale).

The relative scarcity of water and land also might be expected to affect the amount of water sold to other farmers. To control for water scarcity, we include the variable W_j which is measured by the *depth of the groundwater table*. Since the cost of pumping (and, hence, the price at which water can be sold to farmers) is directly related to the depth of the well, we would expect a negative coefficient on the depth of the groundwater table variable. However, it is possible that the sign is positive if as the groundwater table falls (or is lower in level), it is more difficult for farmers to sink their own well and so groundwater markets emerge to meet the demand. We also need to be concerned about the endogeneity of such a variable since the development of groundwater markets may influence the level of the groundwater table. Consequently, in our analysis we measure W_j as the groundwater table of the village in 1995, a time before our sample and a period before the takeoff of groundwater markets. In the same spirit, we include a variable L_j in order to control for the degree of land scarcity (which we measure as cultivated land per capita in the village in which tubewell j is located). Our hypothesis here is that when land per capita is lower, the benefits of investing in one's own well falls and increased the demand for water markets.

In equation (2), as in equation (1), we also include a set of three policy variables and a set of control variables. The first variable equals one if the tubewell owner (or shareholding group) received a fiscally-subsidized rebate after investing in the well (and zero if it was fully self-financed). The second policy variable equals one if the tubewell received a bank loan as part of the investment financing package of the well (and zero if not). Finally, the third policy variable equals one if the tubewell was issued a well-drilling permission certificate before the well was drilled, and zero otherwise. We would expect any policy that facilitates (discourages) the investment in tubewells to increase (decrease) the size and depth of the well, providing individuals with more (less) excess capacity from which they are able to sell water. The definitions (and expected signs) of the other control variables (*village income per capita*; dummy of adopting water delivery pipes) are the same as those in equation (1).

Results

When estimating the determinants of the development of the breadth and depth of groundwater markets, we use a Tobit model. This estimation strategy is needed since the dependent variables in both equation (1) and (2) are in “share” form (that is, between 0 and 1). There are also a number of villages (tubewells) in which the value of the dependent variable is zero. Using Ordinary Least Squares Approach (OLS) would produce bias in the estimated parameters.

Determinants of the Breadth of Groundwater Markets

In estimating equations (1) with our data, our econometric estimation performs well (Table 4, column 1). Most of coefficients of the control variables have the expected signs

and a number of the coefficients are statistically significant. For example, the coefficient of well-drilling permission regulation variable is negative and statistically significant (column 1, row 8).

More importantly, when examining our variables of interest, our results show that the change of tubewell ownership from collective to non-collective induces the development of groundwater markets. The coefficient on the share of non-collective tubewells variable is positive and significant (Table 4, row 1). All other things held constant, when the share of non-collective tubewells in a village increases, the share of tubewells selling water increases. Although we cannot infer causality, this result shows the correlation between privatization and the rise of groundwater markets. One explanation of this is that in villages with more privately owned tubewells, there is more of an incentive to sell water.

Resource scarcity also is associated with the emergence of groundwater markets. Although it could have been that deeper water tables mean higher water prices and less demand, in fact, the coefficient on the depth to groundwater table is positive and significant (Table 4, row 3). Hence, the alternative interpretation is consistent with our findings: in areas in which the groundwater table is deep, farmers demand for water from groundwater markets is higher (relative to providing water from one's own well). In simplest terms, if these results are indicative of underlying causal relations, the findings are evidence of the hypothesis that in villages with scarce water resources, groundwater markets develop more quickly.

Our results also show that land pressure has increased the breadth of groundwater markets. The coefficient on the per capita arable land variable is negative and statistically significant (row 4). In other words, our results imply that with decrease of per capita land resources, the share of tubewells selling water has increased.

Determinants of the Depth of Groundwater Markets

Our econometric estimation also performs well when estimating the depth of groundwater markets (Table 4, column 2). The Chi-square is 46, higher than those above explaining the breadth of groundwater markets. Similarly, most of the coefficients of the control variables have the expected signs and a number of the coefficients are statistically significant. For example, the coefficient on the variable of farmer per capita net income is positive and significant (row 10). This means that rich farmers sell more water than poor ones, or in other words, poor farmers buy more water than others. One implication of this may be that it implies that when there are groundwater markets, and as farmer incomes increase, rich farmers will sell more water to the poor, and in this way can help the poor gain better access to water. In either situation, water is more equitably distributed.

In addition, similar to the regression results on the determinants of the development of the breadth of groundwater markets, the development of the depth of groundwater markets also is significantly associated with tubewell ownership and water and land scarcity. For example, the coefficient on the dummy variable for individual tubewell ownership is positive and significant (Table 4, row 2). This means that compared with shareholding tubewells, individual tubewells sell a higher share of their water. Hence, the alternative interpretation is consistent with our findings: in areas in which the groundwater

table is deep, farmers demand for water from groundwater markets is higher (relative to providing water from one's own well). In simplest terms, if these results also are indicative of underlying causal relations, the findings are evidence of the hypothesis that in villages with scarce water resources, groundwater markets develop more quickly.

Our results also show that land pressure has intensified the breadth of groundwater markets. The coefficients on the depth-from-surface of the groundwater table and the per capita arable land variables are significant regardless of the specification (Table 4, rows 4 and 5). Therefore, it appears that when the groundwater table is deeper (and tubewells need to be larger and more expensive to sink) and agricultural land is more scarce (making it less desirable for an individual farmer to sink his/her own tubewell), the average tubewell operator sells a greater share of water from his/her tubewell.

Do Groundwater Markets Help the Poor?

Based on above analysis, we found that groundwater markets in northern China have developed in terms of both their breadth and depth. Our household data further indicate the importance of groundwater markets for irrigation in northern China. We find that more than 70 percent of the sample's households depend on groundwater to irrigate (Table 5, rows 1 and 2). However, of all of the households using groundwater, only 34 percent of them own tubewells. In contrast, 20 percent of households have to depend on groundwater markets to gain access to water for irrigation (rows 3 and 4). Although a fairly large number of households still access groundwater from collective tubewells, as the

strength of the collective diminishes, it is clear that the role of groundwater markets will become increasingly important in the coming years.

As groundwater markets become increasingly important, it is important to understand if groundwater markets are helping or hurting the poor and/or increasing or reducing inequality in rural China. If groundwater markets emerge and function well, the rise of private tubewells does not have to lead to inequities (although it may—the final answer is an empirical one). Elsewhere in the world, research has shown that groundwater markets can be equity enhancing. For example, in Pakistan Meinzen-Dick and Sullins (1994) demonstrate in their case study area that groundwater markets improve equity of groundwater use by making water available to small landowners or tenants and younger households—those farmers who are least likely to own tubewells.

Our field survey in northern China has provided the similar evidence as that in Pakistan and other countries. According to our data, we find that groundwater markets have provided the groundwater access opportunity to poorer farmers and reduced potential income gaps by enhancing the access to groundwater. Specifically, households in our sample that buy water from groundwater markets are poorer than water-selling households. For example, the per capita income from cropping of water-buying households is only 61 percent of that of water-selling households; per capita total income of water-buying households also is lower than that of water-selling households (Table 5, rows 1 and 2). Such results may imply that, although poor farmers have no money to sink tubewells, they can buy water from markets. If this is the case, groundwater markets almost certainly are helping the poor.

Our data also indicate that groundwater markets benefit weak farmers that are small, less education and older. Households that buy water have smaller holdings of cultivate land than water-selling households. For example, the per capita land area of water-buying households is 0.13 hectare; the land area of water-selling households is slightly larger, 0.15 hectare (Table 6, row 3). Such a findings implies that households with small holdings of land, who are not able to or choose to not sink a tubewell (and can not utilize the entire command area of a tubewell investment) are able to buy water through groundwater markets. In addition, we find that less educated and older farmers also depend more on groundwater markets to gain access to groundwater (rows 4 and 5).

Concluding Remarks

In this paper we have sought to understand the development of groundwater markets in northern China and examine the factors that determine the development of groundwater markets. Using data that we collected ourselves, our findings 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 tubewell owner sells to others on a market basis). Interestingly, although fewer people have worked on groundwater markets in China, even compared to countries, such as India and Pakistan, which have better documented groundwater markets, groundwater markets in northern China clearly have emerged and are almost equal in pervasiveness. Although we find that groundwater markets in northern China have some characteristics similar to those in South Asia (e.g., markets are informal,

localized and mostly unregulated), they differ in other ways. Groundwater markets in northern China appear to be done more on a cash basis and are not fully impersonal.

While our multivariate analysis is carried out mostly to understand descriptively the correlates of groundwater markets, we have a number of robust findings. The form of ownership appears to be correlated with the emergence of groundwater markets.

Groundwater markets also appear in more villages and tubewell owners sell a higher share of the water from their wells when the groundwater table is deep and land is scarce. All of these are suggestive that when the factors that affect supply and demand for groundwater are in place, there is a tendency for markets to emerge.

While much of our results are suggestive that groundwater markets are largely self-organizing and unregulated, there also does appear to be a role for the state. Our findings show that when the government makes it easier for individuals and shareholding groups to get access to capital and are not subject to local regulations, there is greater level of groundwater market activity. Since our results (not shown here for brevity sake) also show that groundwater markets at the very least are not regressive and may, in some cases, be progressive, it may be that government-sponsored investment and banking programs that allow individuals access to grants and loans to sink tubewell will further promote groundwater markets with Chinese characteristics.

Finally, we also found that groundwater markets in northern China do help the poor. We find that households that buy water from groundwater markets are poorer than water-selling households. Such a finding implies that groundwater markets have provided

greater access to groundwater to poor farmers and possibly help reduce income inequalities in rural China.

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Table 1 Development breadth and depth of groundwater markets in 1995 and 2004

| | 1995 | 2004 |
|--|------|------|
| Breadth | | |
| Share of villages having groundwater markets (%) | 9 | 44 |
| Share of tubewells selling water (%) | 5 | 18 |
| Depth | | |
| Share of water sold (%) | 80 | 77 |

Data source: Data in row 1 and row 2 are from authors' survey in 68 randomly selected villages in 4 provinces of NCWRS; Data in row 3 are from authors' survey in 50 randomly selected tubewells in 2 provinces of CWIM.

Table 2 Relationship between development breadth of groundwater markets and tubewell ownership and resource endowment

| | Share of tubewells selling water (%) | Tubewells ownership Share of private tubewells (%) | Water scarcity Groundwater Table (meter) | Land scarcity Per capita arable land (ha) |
|---|--|---|---|--|
| Grouped by year ^a | | | | |
| 1995 | 5 | 50 | 28 | 0.12 |
| 2004 | 18 | 81 | 38 | 0.10 |
| Grouped by share of tubewell selling water ^b | | | | |
| 0 | 0 | 68 | 28 | 0.11 |
| 0-30 | 12 | 46 | 45 | 0.12 |
| 30-90 | 57 | 70 | 48 | 0.11 |
| 90-100 | 100 | 100 | 48 | 0.09 |

^a The number of observations used for each row in rows 1 and 2 is 68.

^b The number of observations used for each row in rows 3 to 6 is n=100(row 3); n=10(row 4);n=8(row 5); and n=18(row 6). Data are averages for two sample years.

Data source: Authors' survey in 68 randomly selected villages in 4 provinces of NCWRS.

Table 3 Relationship between development depth of groundwater markets and tubewell ownership and resource endowment

| | Tubewells ownership | | Water scarcity | Land Scarcity | |
|---|---------------------|--------------|----------------|---------------|-------|
| | Share of | Share of | Groundwater | Per capita | |
| | Water sold | individual | table in 1995 | arable land | |
| | | shareholding | | | |
| | tubewells | tubewells | | | |
| (%) | (%) | (%) | (meter) | (ha) | |
| Grouped by Share of Water sold ^a | | | | | |
| 0 | 0 | 19 | 81 | 13.6 | 0.120 |
| 0-90 | 48 | 44 | 56 | 11.1 | 0.091 |
| 90-100 | 97 | 100 | 0 | 17.6 | 0.089 |

^a The number of observations used for each row in rows 1 to 3 is n=32(row 1);n=9(row 2);and n=9(row 3).

Data source: Authors' survey in 68 randomly selected villages in 4 provinces of CNWRS.

Table 4 Regression analysis of the determinants of development breadth and depth of groundwater markets (Tobit)

| | Share of tubewells selling water | Share of water sold |
|---|-------------------------------------|---------------------|
| Tubewell ownership | | |
| Share of private tubewells | 1.733 (3.28)*** | |
| Dummy of individual tubewell | | 0.389 (4.33)*** |
| Water and land scarcity | | |
| Log of groundwater table | 1.065 (3.17)*** | |
| Log of groundwater table in 1995 | | 0.105 (2.01)** |
| Log of per capita arable land | -1.022 (2.29)** | -0.522 (3.50)*** |
| Policy interventions | | |
| Dummy of fiscal subsidies for tubewell investment | 0.646 -0.68 | -0.121 -1.58 |
| Dummy of bank loans for tubewell investment | 0.488 -0.56 | 0.484 (3.02)*** |
| Dummy of well-drilling permission regulation | 1.429 (2.75)*** | 0.045 -0.46 |
| Other control variables | | |
| Dummy of adopting water delivery pipes | -0.241 -0.65 | -0.093 -0.94 |
| Per capita net income of farmers | -0.006 -0.02 | 0.196 (1.94)* |
| Constant | -8.844 (3.18)*** | -2.943 (3.34)*** |
| Observations | 136 | 50 |
| Chi-square | 18.07 | 46.37 |

Absolute value of z statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5 Participation in groundwater markets of farm households

| | 2004 |
|--|------|
| Total households | 173 |
| Number of household using groundwater | 128 |
| Share of households having tubewells themselves to irrigate (%) | 34 |
| Share of households getting groundwater irrigation through groundwater markets (%) | 20 |

Data source: Authors' survey in 56 randomly selected villages in 2 provinces of CWIM.

Table 6 Characteristics of water-selling and water-buying households in 2004

| | Water-selling households | Water-buying households |
|--|--------------------------|-------------------------|
| Per capita cropping income (yuan) | 1609 | 988 |
| Per capita total income (yuan) | 2891 | 2634 |
| Per capita land area (ha) | 0.15 | 0.13 |
| Education level of household head (year) | 6.3 | 5.5 |
| Age of household head (year) | 47.6 | 50.0 |

Note: The sample number of water-selling households and water-buying households are separately 36 and 25.

Data source: Authors' survey in 56 randomly selected villages in 2 provinces of CWIM.

ⁱ In our studies, northern China is defined to include the following regions: northern China (*huabei*), Northeast China (*dongbei*) and Northwest China (*xibei*).

ⁱⁱ Private tubewells consist of two types of tubewells—individual and shareholding tubewells. If a tubewell belongs to a single individual or family, we call it an individual tubewell. In many cases, however, a tubewell is owned by a group of individuals. Since in many of the groups, the individual members are assigned shares that indicate the investment stake that each member owns in the tubewell entity, the groups are often called shareholding groups and their tubewells are called *shareholding tubewells*.

ⁱⁱⁱ There is a potential asymmetry when trying to match water-selling and water-buying households with households that own tubewells and those that do not own tubewells (henceforth, *non-tubewell owners*). While a non-tubewell owner can only be a water-buying household and can not be a water-selling household, a tubewell owner can be both a water-selling household and water-buying household (for example, in the case when he/she is cultivating a plot that is in a location that can not be supplied by his/her own tubewell).

^{iv} We want to emphasize that in this part of this section of the paper we are only examining correlations with our descriptive data. We are not suggesting causality. The most that we can say with descriptive statistics is that, we are showing data trends that are consistent with the hypotheses. We include a multivariate analysis in the next section.