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

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ABSTRACT

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. The markets have developed in a way in which they appear somewhat similar to markets that are found in South Asia. However, groundwater markets differ from markets in South Asia in other ways—water sellers discriminate in pricing and they almost always work on a spot-market, cash basis (that is, there are no share or labor sharing arrangements as 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; Emergence; Characteristics; Determinants; northern China

JEL Classification Codes: O53; Q15; Q25

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As the reliance on groundwater has increased, China's groundwater economy has become characterized by a growing water crisis (Wang et al., 2005a). With falling groundwater table, the ownership of tubewells also has been evolving from collective to private. 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), it has also made *access to irrigation water* an increasingly important issue. The rise of private tubewells, however, does not have to lead to inequities if groundwater markets emerge and function well. Despite the potential importance of groundwater markets, there is almost no reference in any work on groundwater markets in China in either Chinese or English. The overall goal of our paper is to understand the development and determinants of groundwater markets in northern China.

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 wells. 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.

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. 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.

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.[2] In addition, there was a section that focused specifically on groundwater markets. For example, we asked village leaders if there are tubewell owners that sell water to farm households that do not own tubewells, the number of

[1] In our study, northern China can be thought to include the following regions: northern China (*huabei*), Northeast China (*dongbei*) and Northwest China (*xibei*).

[2] 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 groups of individuals. Since in many of the groups the individual members are assigned shares that indicate the investment stake that each member has in the tubewell, the groups are often called shareholding groups and their tubewells are called shareholding tubewells.

tubewells in a village from which water was sold by its owner and detailed information on the water sales activities of the village's typical well. Both surveys were designed in ways that allowed the construction of data with an inter-temporal component. The surveys collected data on many 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.

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 that were selling water (row 3).

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 where transactions between water-selling and water-buying households are done without legal sanction. Second, groundwater markets in both northern China and South Asia are almost always *localized* (that is, water sales are made to fellow villagers). 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.

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 the groundwater markets. First, Shah (1993) suggests that transactions between water-buying and water-selling households are typically *impersonal*. 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; in other words, there was not a single price for a relative, neighbor or lease of cultivated land. Second, the *patterns of payment* of groundwater markets are different. In South Asia, for example, water-buying households often provide labor or a share of their crop's harvest in exchange for water (Shah, 1998). In northern China, however, water sold in groundwater markets are almost always paid for on a cash basis.

Determinants of Groundwater Markets

According to descriptive statistics based on our data from northern China, we find that groundwater markets are not randomly assigned but appear to emerge in areas bases on the existing resource scarcities and institutional structures. We find that the development of groundwater markets is related (in a descriptive sense) with water resource scarcity (Tables 2 and 3). For example, when the water table falls in the NCWRS sample villages over time (from 28 to 38 meters—Table 2, column 3), the share of tubewells from which water is being sold is higher (columns 1). Likewise, when we divide the tubewells in the sample by the share of tubewells from which water is sold in four groups (column 1, rows 3 to 6), there is a positive correlation between the amount of groundwater activity and level of the groundwater table. Likewise, our data trace similar pattern between groundwater market activity and land scarcity (Table 2, columns 1 and 4; Table 3, columns 1 and 5).

Beyond resource scarcity, our data demonstrate that the development of groundwater market activity is correlated with the private ownership of tubewells (Tables 2 and 3). For example, 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 grouped 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).

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 *breadth of groundwater markets*:

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

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 a set of three policy variables (fiscal subsidies for tubewells, bank loans for tubewells and well-drilling regulations) which are included to assess the effects of policy on the development of groundwater markets. We also control for several other factors, such as the adoption of irrigation water conveyance technologies and village income per capita. The symbols α, β, γ, δ and ϕ are parameters to be estimated and ε_{jt} is the error term.

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

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

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. The relative scarcity of water and land might also 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*. We 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 year in a time period before the takeoff of groundwater markets. In the same spirit, we inlude a variable, L_j, in order to control for the the degree of land scarcity (which we measure as cultivated land per capita in the village in which tubewell *j* is located). In equation (2), as in equation (1), we also include a set of 3 policy and the control variables.

Results

When estimating the determinants of development breath 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 our estimates.

Determinants of Development 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.

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). Our results also show that land pressure has increased the development 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 Development 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 coefficients of control variables have the expected signs and a number of the coefficients are statistically significant.

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 are also significantly associated with tubewell ownership and water and land scarcity. For example, the coefficient on the dummy variable of individual tubewell is positive and significant (Table 4, row 2). This means that compared with shareholding tubewells, individual tubewells sell more water. The coefficients on the depth of the groundwater table and the per capita arable land variables are significant regardless of the specification (rows 4 and 5). Hence, it appears as if 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.

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 suggest 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.

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Table 1 Development breadth of groundwater markets in different period

Year	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

		Tubewells owenership	Water scarcity	Land scarcity
	Share of tubewells selling water	Share of private tubewells	Groundwater Table	Per capita arable land
	(%)	（%）	(meter)	(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 owenership		Water scarcity	Land Scarcity
	Share of water sold	Share of individual tubewells	Share of shareholding tubewells	Groundwater table in 1995	Per capita arable land
	(%)	（%）	(%)	(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	-0.522
	(2.29)**	(3.50)***
Policy interventions		
Dummy of fiscal subsidies for tubewell investment	0.646	-0.121
	-0.68	-1.58
Dummy of bank loans for tubewell investment	0.488	0.484
	-0.56	(3.02)***
Dummy of well-drilling permission regulation	1.429	0.045
	(2.75)***	-0.46
Other control variables		
Dummy of adoption of water conveying pipe	-0.241	-0.093
	-0.65	-0.94
Per capita net income of farmers	-0.006	0.196
	-0.02	(1.94)*
Constant	-8.844	-2.943
	(3.18)***	(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%