

## Characteristics of Groundwater Markets in Northern China: Is It Related with the Local Water Endowment ?

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**Abstract:** China's groundwater markets have been developing rapidly. However, little is known about the variations of these markets across villages. The overall goal of this paper is to have better understanding of the characteristics of groundwater markets and its relationship with water endowments in northern China. Based on our primary field survey data collected in Hebei and Henan provinces, our results show that although there have been a rapid development of groundwater markets in northern China, the development has been very uneven across regions. Moreover, the characteristics of groundwater markets also differ largely across regions. Further analyses show that the market characteristics are closely related with the local water resource endowments. So before policy makers work out any policy related to groundwater economy, great differences of the market operation should be taken into account. The implications of such diversities across regions with different resource endowments should be well understood.

**Key words:** groundwater markets; characteristics; water endowment; northern China

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### 1 Introduction

Groundwater has become the primary source of irrigation water in northern China. According to official statistics between 1965 and 2003, the number of tubewells increased from 0.2 million to 4.7 million<sup>[1,2]</sup>. Nearly all of the tubewells (95%) are located in northern China. By the mid 2000s, these tubewells provided about 68% of the total irrigation water in northern China<sup>[3]</sup>. The rising China's groundwater use has expanded China's farmland and irrigated areas, which contributed significantly to agricultural growth in northern China since the 1980s<sup>[4]</sup>.

Increasing use of groundwater, however, has also resulted in serious challenges in the sustainable use of water resources. For example, groundwater tables have significantly declined in the North China Plain since the 1990s<sup>[5]</sup>. This has been happening in both shallow and deep water tables, and the latter fell more faster than the former. Consequently, the expenses of sinking and operating a tubewell have at least doubled from 1995 to 2004 in many parts of northern China<sup>[6]</sup>. During the course of falling groundwater table, the ownerships of tubewell have also been changed by shifting from collective ownership to individual farmers (or farmers' group)<sup>[7]</sup>.

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The Huai River-Qinling Mountain line is regarded as the geographical dividing line between North China and South China

Recent research found that in response to decline of groundwater table and privatization of tubewells, groundwater markets (or groundwater irrigation service markets) have been emerging and developing rapidly in northern China<sup>[8]</sup>. Groundwater market is an informal institutional arrangement for irrigation service that initiated by farmers. Through this market, tubewell owners of individual or farmers' group sell their water to other farmers who need water for irrigation. Since the ownership of groundwater resources does not belong to farmers but the whole nation, such markets are limited only to local irrigation services. Previous study showed that farmers in only 9% of the villages in northern China got their groundwater irrigation through such markets in 1995. By 2004, villages having groundwater markets increased to 44%<sup>[8]</sup>.

Despite that groundwater market has begun to attract attention of some researchers in China, it is still an area that has not been well documented and studied in the literature. For example, although some studies identified the major determinants of groundwater market and its impacts on water use and agricultural production, almost no study examined the diverse characteristics of groundwater markets and its relationship with water endowment. As pointed out by Wang et al.<sup>[7]</sup> the problems and consequences of groundwater may differ largely across space in northern China. If this is true, then it would imply that an effective policy on groundwater management should be local specific and adapted to local situations.

The overall goal of this paper is to have better understanding of the characteristics of groundwater markets and their relationship with local situation, particular local water endowment. In order to achieve this goal, we try to answer the following questions: What is the current status of groundwater markets in northern China? Who are major players in the market? What kinds of irrigation services are provided by the water sellers? How do the sellers charge fees? Is there any significant variation of groundwater markets among villages? If it is so, what is the major reason for this variation; is it related with water endowments?

## 2 Data

The data used in the study come from our field survey conducted from December in 2007 to January in 2008. In total, 200 households, 20 village leaders and 47 tubewell owners were interviewed. The samples are distributed in 20 villages in four counties in Hebei and Henan provinces located in North China. These four counties are Xianxian and Cixian counties in Hebei Province, and Yanjin and Kaifeng counties in Henan Province. In order to examine the likely linkage between groundwater market and local endowments, we selected our samples to cover a range of water scarcity (e.g., from serious water shortage areas to much less water scarce area) based on the share of irrigated land among the total farmland at county level.

We designed three kinds of surveys, including surveys of farmers without tubewell, farmers with tubewell, and village leaders. For farmers without tubewell, the survey included household's basic characteristics, possible ways to access water, income information, and details information on water use, fees charging and adoption of water saving technologies. In the tubewell owners' survey, besides most of the questionnaires included in the survey of farmers without tubewell, significant efforts were made in getting information on the characteristics of the tubewells, irrigation

activities, water services and the fees charged for the services. For the village leader survey, it covered the general social and economic information, any government regulations on the price of water sold from tubewells, and the water resource endowments at village level. The survey also tabulated the number of tubewells in the village from which water was sold by its owner in 2004 and 2007.

### 3 Characteristics of groundwater markets

#### 3.1 Development of groundwater markets in northern China

Our results show that although groundwater markets are found in most of the villages surveyed, yet the years started groundwater market differed largely among villages (Table 1). Based on the village survey, we found that, in our samples, there were 75% of the villages had developed groundwater markets before the end of 2007. Among those villages with groundwater markets, there were 20% of the villages already started their groundwater markets in the 1980s. These villages are mostly located in Cixian County of Hebei Province. After the early 1990s, the development of groundwater markets had accelerated. Especially from 1991 to 2000, 47% of the villages developed their groundwater markets. Most of the villages in the Xianxian County of Hebei Province and Yanjing County of Henan Provinces began to develop groundwater markets during this period. The rest or one third of the villages with groundwater markets started their markets after 2001, especially in Kaifeng County of Henan Province.

**Table 1 Shares of villages with groundwater markets in 1980 - 2007**

	Share of villages/%
Villages without groundwater markets by the end of 2007	25
Villages with groundwater markets by the end of 2007	75
The periods started groundwater markets	
1980 - 1990	20
1991 - 2000	47
2001 - 2007	33

Data source: Authors' survey.

Groundwater markets differ largely across villages not only in terms of their starting years, but also the level of market development (Table 2). We follow the way of Zhang *et al* <sup>[8]</sup> to calculate the breadth and the depth of the groundwater development. That is, we use the share of tubewells selling water in the village to indicate the breadth of groundwater markets, use the share of water volume sold by the tubewells' owners over the total pumped water volume to indicate the depth of groundwater markets development. Our results show that although there were variations, groundwater markets in most villages have developed very well. For example, as shown in the column (II) and fourth row of Table 2, most of the tubewells (more than 75%) in 60% of the villages sell water to farmers. In other 40% of villages, the share of tubewells selling water ranges from 25% to 75%. The similar story can be found when we look at the depth of groundwater markets. For example, in 79% of the villages, tubewell owners sell more than 75% of the total pumped water to other farmers in their villages (column III, row 4). For the rest of the villages,

the share of water sold by tubewell owners ranges from zero to 75%. In addition, we found that either in terms of breadth or in terms of depth, the development level of groundwater markets in Cixian County of Hebei Province is higher than the other three counties. All the above evidences imply that there is great heterogeneity of development level of groundwater markets throughout North China.

**Table 2 Shares of villages with different development levels of groundwater markets in 2007 (%)**

Village groups by breadth or depth of markets ( I )	Shares of villages based on the breadth of groundwater markets in column ( I ) / % ( II )	Share of villages based on depth of groundwater markets in column ( I ) / % ( III )
0% - 25%	0	7
25% - 50%	27	7
50% - 75%	13	7
75% - 100%	60	79
Total	100	100

Date source: Authors' survey

### 3.2 Sellers and buyers in the market

Our survey also shows that in most villages water sellers are relatively rich farmers, and buyers are poorer farmers. In the survey, five income categories are used to measure the relative income levels within the village, ranging from the lowest (1) to the highest income (5). Farmers with income level higher than 3 are considered as rich farmers and the rest in the village are considered as poor farmers. Results show that within 67% of the sample villages, they are rich farmers who are selling water. The villages having poor farmers to sell water only occupy 33% of the total samples (Table 3). Different from sellers, most water buyers are poor farmers. For example, in 60% of the sample villages, poor farmers are acting as water buyers, while in other 40% of the sample villages rich farmers are acting as water buyers. Our results imply that groundwater markets provide an effective way for poor farmers to access groundwater resources.

**Table 3 Shares of villages with different income levels of water markets players in 2007**

		Shares of sample villages / %
Water sellers		
	Rich farmers	67
	Poor farmers	33
Water buyers		
	Rich farmers	40
	Poor farmers	60

Note: Rich farmers' income level is higher than 3 and poor farmers' income level is lower than 3. Data source: Authors' survey.

### 3.3 Irrigation services in the markets

Based on our survey, we found that there are three types of irrigation services in the groundwater markets. First, the sellers not only dig a well and pump water out, but also convey water by underground pipe to farmers' plots or some places very near to the plots. In most cases when sellers provide water with underground pipes, farmers only need several sections of plastic hose that

every farmer can easily afford connected with the nearest outlets to their plots. The first type of service is most complicated and we define it as triple service. Second, sellers are only responsible for digging wells and pumping water out. Conveyance work is totally done by buyers themselves, mostly with white hoses or canals. We define such service as double service. The last type of service is the simplest service. In this case, the service remains completely self-help. Farmers drive their own tractors to the spot where the seller's tubewells are located, sink their own pump, and then extend their own white hoses to their plots. In this entire irrigating course, the sellers are absent. The only service that they provide is to dig a well. We define such service as single service.

Our results show that the importance of various irrigation services is different by region. On average, the share of plots serving by the double services is higher than other two types of services (Table 4). For example, in 2007, the share of farmers' plots irrigating through the double services was 39%, while it was 31% for single service and 69% for triple service. In Xianxian County, the major type of irrigation service in the groundwater markets is triple service; there are 69% of farmers' plots buying water through service. The double service is the major pattern of irrigation service in Cixian County (77%), while in the Yanjin County, the major pattern of irrigation service is single service (96%).

**Table 4 Share of plots with different types of service in three counties where water market have emerged, 2007**

	Triple service /%	Double service /%	Single service /%
Xianxian county	69	31	0
Cixian county	23	77	0
Yanjin county	4	0	96
Average	30	39	31

Note: Triple service = digging tubewells + pumping out + delivering to the field; Double service = digging tubewells + pumping out; Single service = digging tubewells

Data source: Author's survey

### 3.4 Approaches of charging irrigation fee and the level of irrigation fee in the markets

According to our survey, there are three approaches for sellers to charge irrigation fee of selling water. The first one is that the sellers charge irrigation fees based on the plot area. Such charging approach is mainly adopted by 15 sample tubewells owners in the five sample villages in Yanjin County of Henan Province. In this county, village committees sold collective tubewells to farmers at a relative low price. However, even the tubewell ownership has changed, the village committees still control the water selling price, which cannot be higher than 30 yuan per hectare. The second approach is to charge irrigation fee based on irrigation hours. There are 45% of the tubewells owners and 40% of the villages adopting such approach. Such approach is mainly in the Cixian County in Hebei Province. The third approach is to charge irrigation fee based on the electricity use through reading electrical meter. There are 23% of the tubewell owners and 33% of the villages adopting such approach. Such approach is mainly adopted by farmers in the Xianxian County. Compared with the first approach, the second and third charging approaches can be treat-

ted as volumetric pricing approach since irrigation fee is indirectly (such as the second approach) or directly (such as the third approach) related with the volume of irrigation water use.

In addition to the different approaches of charging irrigation fee, the level of irrigation fee charged also differ by tubewells and villages. In our four sample counties, we use two of them to address the problems related to water price, because of the absence of groundwater market in Kaifeng County and the flat pricing policy in Yanjin County. Our irrigation price data is based on each round of irrigation of each plot of farmers. After we drop those observations using surface water and rainfed, we get 617 observations. Just as the former part of this paper shows, market prices of water also could be highly uneven. In Fig. 1, it is found that great variation exists across villages. Village average price range from 0.16 to 0.60, the highest could be about 4 times as much as the lowest. On average, irrigation price is higher in Xianxian County ( $0.46 \text{ yuan/m}^3$ ) than in Cixian County ( $0.24 \text{ yuan/m}^3$ ).

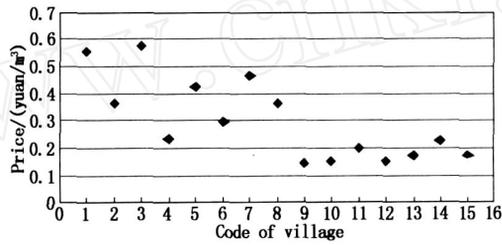


Fig. 1 Irrigation price by villages

#### 4 Relationship between characteristics of groundwater markets and water endowment

According to previous research, the characteristics of groundwater markets are possibly related with water endowment. Zhang *et al.*<sup>[8]</sup> found that water scarcity could significantly affect the emergence of groundwater market. Shah<sup>[9]</sup> also shows that the availability of water resources is correlated with the development of groundwater markets. Strosser and Meinzen-Dick<sup>[10]</sup> suggest that the depth of the groundwater table is an important factor affecting groundwater markets. The water endowment is quite unevenly distributed in northern China. For example, the average level of water table of 20 sample villages in 2007 is 36.4 m, while the water table in Xiaogang village is 2.5 m and the water table in Hutun village reaches to 170 m. So, it is possible that the characteristics of groundwater markets (such as the development of groundwater markets, irrigation services and the fees charged) could be affected by water endowment.

In this section, we try to understand whether and how the characteristics of groundwater markets are correlated with water endowment. In order to examine this issue, we grouped our villages by various conditions of water endowment in terms of groundwater table in each village in 2007. Villages with a water table less than 50 m are considered as water abundant villages, otherwise, if water table is more than 50 m, such villages are considered as water scarce villages.

Irrigation price is estimated based on the following detail information, such as irrigation hours, electricity or diesel oil consumed, expense and the actual pumped water volume per hour.

Our data show that groundwater markets are more possible to emerge in villages with poor water endowment. In our 20 sample villages, 15 of them developed groundwater market while in 5 of them, groundwater market is still absent. Difference on water endowment between these two kinds of villages is obvious. For example, the average groundwater table of those 15 villages with groundwater market is 47 m while for those 5 villages without groundwater market, their average groundwater table is only 6 m. In addition, in the water scarce villages, groundwater markets began to operate in 1985, while in water abundant villages, groundwater markets have not emerged until 1991 (Table 4). Our *t* statistics also indicate the significant difference on the emergence year of groundwater markets between water abundant and scarce villages. This is also consistent with the results of Zhang *et al* <sup>[8]</sup> that the scarcity of water could accelerate the emergence of groundwater market.

Water endowment is also possibly correlated with many other aspects of groundwater market. This can be found in Table 5. First, the development degree of groundwater markets is higher in water scarce villages than in water abundant villages. For example, in 2007, the breadth of groundwater market development was about 79, while it was only 50% in water abundant villages. The depth of groundwater markets development in water scarce villages was 80%, higher than those water abundant villages (54%). In 2004, we can find the similar story and its difference is statistically significant.

**Table 5 Relationship between characteristics of groundwater market and water endowment**

	Water abundant villages	Water scarce villages	<i>t</i> statistics
Development status of groundwater market			
Emergence year	1991	1985	2.73 **
Breadth (share of tubewells selling water, %)			
2007	50	79	- 1.52
2004	44	78	- 1.62
Depth (share of water sold by tubewell owners, %)			
2007	54	80	- 1.27
2004	18	48	- 2.79 **
Irrigation services in the market (share of villages, %)			
Share of triple service	17	63	- 11.64 ***
Share of double service	40	37	0.91
Share of single service	43	0	19.56 ***
Approaches of charging irrigation fee (share of tubewells, %)			
By plot area	45	0	35.5 **
By hour	48	30	7.05 ***
By electricity used	7	70	20.26 ***
Irrigation fee in the market (yuan/m <sup>3</sup> )	0.22	0.46	- 23.5 ***

Note: 1) Triple service = digging tubewells + pumping out + delivering to the field, Double service = digging tubewells + pumping out, Single service = digging tubewells 2) \* significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%;

Data source: Authors' survey

Second, the ways of services in groundwater market also correlate with water endowment. Our data show that the single and double services are more likely provided in water abundant villages, while the triple service is more likely provided in water scarce villages. The share of plots served with triple service is 63% in villages with lower water table, which is much higher than it in villages with abundant water resources. The *t* statistics also indicate their significant difference between water abundant and water scarce villages.

Finally, our data further indicate that the charging approach of irrigation fee and the level of irrigation fee are possibly corrected with water endowment. First, results show that charging irrigation fee by plot area and irrigation hours are more likely to be adopted in water abundant villages, while in water scarce villages most of the tubewell owners charged irrigation fee based on electricity used. In those water scarce villages, 70% of tubewells charged irrigation by electricity used, while this number is only 7% in water abundant villages. Second, the average price of water in villages with poor water resources is more than 2 times as the price in villages with relatively abundant villages. Either for the approaches of charging irrigation fee, or the level of irrigation fee, the *t* statistics are all significant; it means that they are obviously related with water endowments.

## 5 Conclusion

This paper tries to understand the characteristics of the groundwater markets in North China. Using our field survey data, research results shows that though the groundwater markets are developing fast in North China, the development is not synchronous. When examining the market by dividing it into different parts, we find that each part is showing its difference across regions. To understand this, we descriptively examine the relationship between water resource endowments and the diverse characteristics of groundwater markets.

Particularly, the development levels (both breadth and depth) of groundwater market in water abundant villages are generally lower than in those water scarce villages in 2004 and 2007. Besides, when looking at the service provided by the market in a perspective of water resources constraints, though water scarcity is always related to higher cost in digging deeper tubewells, better services are more probable to be provided for water buyers. Our results also show that sellers in water scarce villages often use more formal method to measure the water fees. Meanwhile, water price is also higher in water scarce villages.

Groundwater markets development and operation show great differences in North China. Water resources constraints are always acting as one of the major factors determining how the markets are conducted. As a result, there are both bad news and good news for those farmers in water scarce areas. The bad news is that they are facing higher cost to dig, and higher water price. As for the good news, there are relatively developed groundwater markets in water scarce areas, using more formal method to measure water payment and providing better services.

As it is shown above and most other literatures, groundwater markets are playing an important role for farmers to access water. However the role as well as the way is played unevenly. Before policy makers work out any policy related to groundwater, great differences on the operation should be taken into account. The implications of such differences for regions with different re-

source endowments should be well understood

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## 中国北方地区地下水市场特征及其与当地水资源禀赋的关系研究

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**摘要:** 中国地下水市场发展迅速,然而关于市场特征在不同地区的差异性的研究并不多见。论文利用河北和河南两省的实地调查数据,分析了北方地区地下水市场特征的地区差异,及其与当地水资源禀赋的关系。研究发现,地下水市场发展在不同地区之间存在显著的不同步性,因而表现出显著不同的运作特征和方式。进一步研究发现,这些市场特征差异和当地的水资源禀赋状况密切相关。因此在地下水市场相关政策的制定过程中,必须充分考虑各地的水资源禀赋状况,并深刻理解其对于地下水市场发展和运行的含义。

**关键词:** 地下水市场;特征;水资源禀赋;中国北方地区