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Does output market development affect irrigation water institutions? Insights from a case study in northern China

Lei Zhang[a,b,*], Xueqin Zhu[c], Nico Heerink[a,b], Xiaoping Shi[a]

[a] China Centre for Land Policy Research, Nanjing Agricultural University, Nanjing, PR China
[b] Development Economics Group, Wageningen University, Wageningen, The Netherlands
[c] Environmental Economics and Natural Resources Group, Wageningen University, Wageningen, The Netherlands

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ABSTRACT

The main aim of this paper is to examine the impact of changing external conditions on irrigation water institutions in northern China. To this end, we perform a case study analysis of the impact of output market development on irrigation water transactions, using survey data collected among 315 households in Minle County, Zhangye City, Gansu Province, covering the year 2009. Households in this region possess tradable water use rights. Moreover, a major agro-processing company has recently been established and the local government intervenes in the allocation of water to stimulate farmers to grow a cash crop for that company. Despite these favourable enabling and driving factors, we find that market water trade is virtually absent. Instead, we observe that reciprocal water use arrangements (water swaps) have emerged at a limited scale. We argue that factors other than an improvement in the output market (such as producer ignorance, centrally set prices, trust) need to be considered, if improvement in the market for irrigation water is to occur.

1. Introduction

China is a country with substantial water resources, but their regional distribution is highly unequal. Water availability in the north (757 m^3 per person in 2003) is almost 25% below the internationally accepted water scarcity threshold of 1000 m^3 per person, while water availability in the south (3208 m^3 per person in 2003) is relatively abundant (Shalizi, 2006).

The water resources available for agricultural production in China are rapidly declining due to increased water demand for industrial use and household consumption. The use of water in agriculture as a share of total water use has steadily declined from around 80% in 1980 to 61.3% in 2011 (Shalizi, 2006; National Bureau of Statistics of China, 2012). Technical innovations as well as water policy and management reforms are required to improve water use efficiency in agriculture to meet growing food demands (Rosegrant and Cai, 2002; Yang et al., 2003). The Ministry of Water Resources of the PR China has initiated a number of pilot projects to gain experience with the development of water-saving irrigation systems. The first of these pilot projects was initiated early 2002 in Zhangye City, an oasis with rich agricultural resources in Gansu Province in northern China. Measures taken under this project include the construction of an engineering system that optimizes the water distribution and an innovative system of water resources property rights allocation and trading.

Zhang (2007) and Zhang et al. (2009) examine the water property rights system that was implemented in Zhangye City. These studies find that high transaction costs in some parts of the region, and management, legal, administrative and fiscal barriers in cases where transaction costs are low, discourage farmers from saving and trading surplus water. As a result, trading of water use rights is almost non-existent in this pilot project area.

Induced institutional innovation theory suggests that new institutions, such as tradable water use rights and non-market institutions, may emerge when resources become more scarce due to growing population density, commercialization of agriculture, or exogenous technological change (Hayami and Ruttan, 1985; Platteau, 1996). Although the theoretical literature elaborating the gains from institutional changes is vast and growing (Bromley, 1989; Saleth and Dinar, 2000), empirical studies examining drivers of institutional change are scarce due to lack of suitable data sets. Appropriately chosen case studies can provide deeper insights into the role of changing external conditions in stimulating institutional change, and may be used to formulate hypotheses on driving forces of institutional change that can be tested at a larger scale.

In Minle County, one of the six counties in Zhangye City, a large potato processing factory was established in 2008. The factory is owned by Aviko Gansu Potato Processing Co., Ltd., a joint venture of Aviko – one of the four largest potato processing companies in the world – and the local government of Minle County. To meet

* Corresponding author. Tel.: +31 647754258; fax: +31 20 4852623.
E-mail address: zhanglei_84@163.com (L. Zhang).

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the demand of this factory, the area grown with potatoes in Minle County is rapidly being expanded at the instigation of the local government. Potatoes need a relatively large amount of water, but the water should be applied at a later stage in the season than many other crops grown in the region. A detailed examination of the changes in the allocation of water to farm households and the trading of water by households that occurred since 2008 in Minle County may add to a better understanding of the impact of output market development on water institutions. Given the fact that Minle County is located within the water-saving pilot area of Zhangye City, such research may also provide important insights into further policy reforms that are needed for establishing an efficient system of water resources property rights allocation and trading.

The objective of this paper is to examine the changes in water institutions that took place in Minle County, northern China after the establishment of a large potato processing company in 2008, and the driving forces of these changes, and to use the resulting insights to formulate policy recommendations on ways to improve the functioning of water institutions. To this end, we use data collected for the year 2009 among 315 households to assess the frequency of water exchanges after the company was established, and to examine factors affecting water exchanges between households. We find that despite the development of the output market, no significant water trading emerged. Information asymmetry between government and water users severely constrains the water use rights exchanges in the region, while low levels of non-kinship trust among villagers entail that most observed exchanges take the form of water swapping instead of market exchanges. We conclude that without addressing these bottlenecks, output market development is unlikely to boost the development of a tradable water use rights markets.

In the next section we present the theoretical framework, focusing in particular on efficiency gains obtained by market and non-market water institutions, the role of transaction costs, and the impact of exogenous and endogenous factors on water management institutions. Recent developments in irrigation water management in China are briefly summarized in Section 3, while the research area (Minle County, Zhangye City) and the data collection method are introduced in Section 4. In Section 5, we use the survey data and insights gained through informal field visits to examine water exchanges that occurred in the year 2009 and to explain the very limited development of market and non-market water institutions in the region. The conclusions of our study and recommendations for further research and for policy making in this field are presented in Section 6.

2. Theoretical framework

Water is used for many purposes such as irrigation in agriculture, hydropower generation, domestic consumption, industrial use and for environmental purposes. Water has an economic value in all its competing uses and should therefore be treated as an economic good (ICWE, 1992). Due to its physical attributes, however, natural water is not a standard (private) economic good. Due to its fluid nature, exclusion is frequently impossible or may be obtained at high costs. The consumption of water is considered by humans as non-rival and non-exclusive when it is available in abundant quantities. It stops being a pure public good when the consumption or use by one person affects the utility or production possibilities of others. But, like many other environmental resources, it tends to remain non-exclusive long after it first became rival (Ellis, 1993, pp. 259–260).

With rising water scarcity, due to population growth, economic development or other factors, the need for social investments in barriers to access rises. Appropriate water institutions (such as well-defined water rights and water markets) are required to achieve an efficient allocation of water over its users such that the total net benefits of water are maximized. Water institutions can be defined as the humanly devised constraints that regulate water development, allocation and utilization. Different institutions are combined in reality for water management, and continued public sector participation is required to deal with the common property character of water and to address externalities[1] (Griffin, 2006). As a result, various types of water institutions have been established in different areas around the globe.

According to the first welfare theorem, Pareto efficient allocations of water can be achieved by establishing water property (use) rights and water markets, provided transaction costs are zero and a number of additional conditions, such as absence of externalities, are satisfied. A resource being managed as a transferable property will cause a market to arise and the market will produce a resource-conserving signal, namely its price (Griffin, 2006). When individual agents possess property rights in (natural) water, they will be able to exchange water for money or other property.

Water trading means the exchange of water rights by willing buyers and sellers. Water trading is a scarcity-addressing strategy to achieve Pareto efficiency because water can be used to its highest value, when the conditions under which the first welfare theorem holds are met (e.g. Zhu and Van Ierland, 2012). Economic theory suggests that, in a perfect market with full information, trading of water takes place until the marginal net benefits of all users are equalized. When a water trading scheme is implemented, the amount of water being transferred therefore depends on the differences between the marginal net benefits of different users. With a relatively large difference in marginal net benefits, water users are expected to trade water (transfer water rights). If there exist only small differences between the marginal net benefits, the traded amounts are expected to be small.

The existence of imperfect information in water market operations, however, contributes to high costs of searching, bargaining and other transaction costs that can pose a serious hurdle for direct market exchanges. Under such conditions, water transactions may take place through non-market institutions. The transaction cost approach in the so-called new institutional economics (NIE) provides an appropriate tool to understand market and non-market exchanges under non-zero transaction costs (Williamson, 1979, 2007; Jia and Huang, 2011). Several basic forms of (market and non-market) water transactions can be distinguished, including exchanges in kind, temporary rentals, permanent sales of rights, and various forms of option contracts (Young, 1986).

From the transaction costs perspective, the difference between two traders' marginal benefits of water evaluated at their initial holding levels must be large enough to offset the marginal transaction costs involved in water trading under market institutions. If transaction costs are high, especially when they exceed the differences in marginal benefits for many potential traders, they may become an obstacle to water trading. In such cases, non-markets institutions can serve as market substitutes for better resource allocation by economizing on transaction costs; well-known examples of non-market institutions that have developed to reduce transaction costs in insurance, credit and labour markets include share cropping, contract farming, and reciprocal labour sharing (Hubbard, 1997; Gilligan, 2004; Williamson, 2007; Jia and Huang, 2011; Takasaki et al., 2012). In transaction cost economics, "economizing on transaction cost is taken to be the cutting edge, [. . ..]:

[1] In this study, we focus on the functioning of a water market which is an important element of the water-saving pilot project in Zhangye City. Potential externalities such as salinity of water are neglected, because the main water source in this region is surface water.

Transactions, with different attributes, are aligned with governance structures, which differ in their cost and competence, so as to effect a transaction cost economizing outcome (Williamson, 2007, p. 17).

An important institution that receives much attention within NIE is that of contracts. Contracts can be defined as the means whereby parities design transactions to their mutual advantage (Hubbard, 1997). Contracts can be formal and informal. An example of (usually informal) contracts are agricultural labour exchanges in which multiple farmers temporarily pool their labour into teams and complete a task on each team member's land in succession. These strict reciprocal labour-sharing arrangements without payments allow working capital constrained farmers in developing countries to increase their productivity in the context of credit and labour market imperfections (Gilligan, 2004). Incentive and/or enforcement problems may be mitigated in team work through reputation mechanisms to secure future labour on the own farm, mutual monitoring, social norms and peer pressure. In a case study on forest clearing among shifting cultivators in the Peruvian Amazon, both the efficiency and productivity of labour-sharing institutions is found to be higher as compared to labour market exchanges under credit market imperfections (Takasaki et al., 2012).

Likewise, a theoretical justification exists for reciprocal water-sharing use arrangements because of its Pareto efficiency. Analogous to reciprocal labour sharing arrangements, smallholder farmers in thin agricultural water markets may use reciprocal water use arrangements to realize efficiency gains in water use while economizing on the transaction costs involved in water trading. To our knowledge, this alternative to market exchanges of irrigation water has not been examined in the literature so far.

An important factor affecting transaction costs in market and non-market exchanges is trust. In the absence of sufficient trust, market participants must protect themselves against moral hazard or even theft through monitoring, contract writing and other costly initiatives, and should be prepared to litigate in case of default. In low-trust societies, people are therefore more likely to use informal arrangements, trading only with people they know and relying on informal punishment mechanisms (Easterly, 2005). Supportive empirical evidence is provided by Tu and Bulte (2010) in a study of rice farmers in southeast China. Making a distinction between local trust (trust among friends and family) and general trust (trust towards the community more broadly defined—encompassing a greater set of potential trading partners), their study finds that high levels of general trust are associated with the use of labour markets, while high levels of local trust are associated with a greater probability to engage in reciprocal labour sharing arrangements. By the same token, general and local trust can be expected to play important roles in household decisions on using either formal water markets or informal non-market exchange mechanisms.

Efficiency gains of different market and non-market water institutions are achieved through changes in the production costs (transformation costs) of water users (Saleth and Dinar, 2004; Griffin, 2006; Zhu and Van Ierland, 2012). The type of water institutions in place greatly affects the efficiency of water allocation. The performance of water institutions can therefore be viewed from the perspective of their functioning, i.e. operations such as active transfers of water rights. Various factors affect this relationship between the performance of water institutions and the efficiency gains of water users. Previous studies make a distinction between endogenous factors, such as water scarcity and financial constraints, and exogenous factors, such as macroeconomic reform, political reform, international agreements, natural calamities, and technological progress (e.g. Saleth and Dinar, 2000).

With respect to endogenous factors, the relative scarcity of water and the transaction costs required to enforce water rights and establish water markets are found to have significant impacts on the functioning of water institutions. Water scarcity, arising e.g. from competing uses of water, creates an endogenous pressure for change, inducing change in the performance of water institutions and thus water-using sectors (Saleth and Dinar, 2004). In locations where market exchanges are novel or infrequent, transaction costs can be especially high due to a lack of familiarity either by market participants, their legal representatives, or the administrative agency (Griffin, 2006).

The performance of water institutions is also affected by exogenous factors such as historical forces, political arrangements, demographic conditions, resource endowments, and economic development. Economic policies, especially macroeconomic and trade (export market) reforms, also play an important role in providing impetus for institutional changes within the water sector (Saleth and Dinar, 2004).

Given that various (endogenous and exogenous) factors influence the performance of water institutions, it follows that similar water institutions that operate in different environments may greatly differ in their performances. It also means that the actual performance of an existing water institution in a given setting is an empirical question. Gaining insights into the most important factors explaining institutional change and performance in the water sector is not only relevant from a scientific point of view, but may also contribute to the design of policies that stimulate a more efficient use of limited water resources. This study intends to add to the literature in this field by performing a case study of the impact of agricultural output market development on the development and performance of water market exchanges and reciprocal water use arrangements.

3. Irrigation water management in China

Before the agrarian reforms in China in the late 1970s, water resources were managed primarily through collective ownership arrangements. Since the start of the reforms, a variety of institutional arrangements have been established to govern water resources (Mukherji and Shah, 2005; Zhang et al., 2008). Besides contracting out of water management and joint management through water users associations (WUAs), recent changes in irrigation water management in China mainly involve tradable water use rights and introduction of water pricing (Qu et al., 2011; Wang et al., 2010).

The establishment of water markets was made possible by the revised national Water Law that came into force in late 2002 (Yuan and Chen, 2005). However, water markets in China are at an elementary stage and are generally occurring outside of a structured trading framework (WET, 2007). Examples of water use rights (WUR) exchange to date mainly include sales from one local government to another, and the transfer of WUR from irrigation districts to industries following water efficiency initiatives (Speed, 2009). Notably, these have been driven by the relevant governments and not by the free market (Speed, 2009).

Water was generally considered a free good until the start of the market-oriented agricultural reforms at the end of the 1970s. Since then the central government encouraged the adoption of a system of volumetric surface-water pricing because prices may provide incentives for using water more efficiently (Lohmar et al., 2003; Qu et al., 2011). Water fees were gradually introduced and increased in an effort to meet the cost of water supply and improve water efficiency. Current prices charged for irrigation water, however, are generally believed to be well below levels that are efficient (i.e. that markets would set). Irrigation water prices often do not even cover the costs of operating and maintaining irrigation systems (Hussain, 2005; Wang et al., 2004; Yang et al., 2003). This may hinder the efficient allocation of water under the prevailing water institutions.

4. Description of the research area and data collection

In our research we use information that we collected via a household survey held in Minle County, Zhangye City, Gansu Province. In this section we first introduce the research area and then briefly discuss the method of data collection.

4.1. Research area

Zhangye City is an oasis located midstream of the Heihe River, an inland river that flows across Qinghai Province, Gansu Province and Inner Mongolia Autonomous Region. The river originates from the Qilianshan Mountains in Qinghai province, crosses the Hexi corridor in Gansu Province, and ends in Juyanhai Lake in Inner Mongolia. In the midstream of the Heihe River watershed, the land is flat, sunshine is abundant, and annual precipitation is very low while the evaporation is high. But due to the availability of irrigation water from the Heihe River, the area has become a major grain and vegetables production base in Gansu province.

According to the Ministry of Water Resources (2004), Zhangye City is severely short of water resources, even though it uses up almost all the water of the Heihe River. Only 50% of the farmland is well irrigated, and much arable land has been abandoned due to water shortage. Agriculture accounts for approximately 95% of all water use and almost all water in the Heihe River is extracted for irrigation use. As a result, too little water flows into Juyanhai Lake. The lake dried out in 1992 and an area of 200 km^2 around the lake became a desert (Zhang et al., 2009).

Minle County is located between the foothills of the Qilianshan Mountains and the lower lying Hexi corridor. Its total cultivated land area equals 860,000 mu [2], with irrigated land constituting 67%. Major crops in Minle County include barley, wheat, maize, sesame, rapeseed, garlic and potato. Surface water is the major water resource for irrigated agriculture in the area. According to the Water Bureau of Minle County, the use of groundwater is less than 5% of total water use in irrigated agriculture due to the high costs of pumping water from the wells.

Precipitation is Minle County, as in other parts of Zhangye City, is unevenly distributed. The wet season is from May to September; it provides around 80% of yearly rainfall. The dry season is from October to April. Irrigation in Minle County is carried out from the beginning of May to late-August. The period until June has a peak demand for water, but the rainfall during those two months is limited. These two months are known by local farmers in Zhangye City as the 'choked period' (Chen et al., 2005).

The water used for surface irrigation in Minle County is stored in seven reservoirs in the Qilianshan mountains, serving five irrigation areas within Minle County. A county-level water management bureau (WMB) supervises the water allocation institutions within the region.

Five lower-level WMBs, one for each of the five irrigation areas, arrange the water allocation to WUAs within their own irrigation area. A standard water allocation quota is assigned to the so-called WUR land of the WUAs within the irrigation area served by a WMB. Not all the irrigated land is classified as WUR land. Its size depends on the labour that was provided by a village to the construction of the reservoirs, the WUR land obtained by a WUA through auctions, and other factors. Based on the actual availability of water in a reservoir in each year, a certain percentage of this standard water quota is actually distributed to the WUAs within the irrigation area of a WMB.

WUAs are responsible for arranging the water allocation to its member households. The households within each WUA are sub-divided into water user groups (WUGs), consisting of households having plots along the same channel. Since the plots of different households within a WUG are irrigated at the same time, households belonging to a WUG need to coordinate their planting decisions and water demands. Water use is measured at the entrance of the second-level canals, and corrected for estimated losses that occur between the point of measurement and the destination point. The water price charged was approximately 0.09 RMB/m^3 in 2009 [3]. Households can trade their WUR with other households, provided the price that is charged does not exceed 0.3 RMB/m^3.

The new potato processing company that was established in Minle County in 2008 demands a specific variety of potatoes, named Atlantic potatoes, for processing into flakes and starch. In order to meet the growing demand for Atlantic potatoes, the local government (which owns a major stake in the new factory) assigned quota for Atlantic planting areas to lower level governments. And it also ordered the WMBs (the 'sellers' of irrigation water) in the region to give priority to land planted with Atlantic potatoes in the allocation of water to the WUAs with in their districts.

The water allocation priority policy requires that in spite of the water scarcity in the region, a sufficient amount of irrigation water has to be reserved for irrigating Atlantic potatoes. The remaining quantity of irrigation water is allocated to land planted with other crops. Specifically, water is allocated to Atlantic potatoes according to its actual planting area, while water allocation to other crops is based on the WUR area. Normally the WUR area is smaller than the actual growing area[4]. Moreover, one to three rounds[5] of irrigation are carried out for most crops, while four or five rounds are carried out for Atlantic potatoes.

4.2. Data collection

A household survey, covering the year 2009, was held in Minle County in May 2010. One of the purposes of the survey was to examine the changes that took place in irrigation water allocation and water markets since the establishment of the new company and the concomitant expansion of the potato market. In a baseline survey, covering the year 2007 and carried out in May 2008, irrigating households were found not to undertake any (market or non-market) water transactions.

The household survey in May 2010 was carried out by staff and students from Gansu Academy of Social Sciences, Gansu Agricultural University, and Nanjing Agricultural University. The dataset includes information about, among others, crop production, use of water and other inputs, water transactions, WUA participation, water and other prices, land tenure and land use. To ensure that all townships would be equally represented, the population in Minle County was stratified into 10 townships. Ten percent of the villages in each stratum were randomly selected, giving a total sample of 21 villages. In each of the 21 selected villages, 15 households were randomly selected to be interviewed. This gave us a dataset containing 315 observations[6] (see Wachong Castro et al., 2010, and Ma et al., 2013, for more information).

Table 1 presents background information for some key variables that were investigated in the survey. The average land holding size

[2] One mu is equal to 1/15 ha.

[3] 1 USD = 6.83 RMB (2009).

[4] The average proportion of WUR land in total arable land is 72.6% for all households in our sample.

[5] Depending on their altitudes, some villages receive one or two rounds of irrigation, while others receive three rounds.

[6] Out of the 315 households that were interviewed in the 2009 survey, 265 households were also interviewed in the baseline survey covering the year 2007. The other 50 households could not be found, and were replaced by other randomly selected households within the same village.

Table 1
Descriptive statistics of some key variables in the household survey.

Agricultural production inputs						
Variables	Unit	No. of observ.	Mean	Std. Dev.	Min	Max
Land	mu	312	19.6	11.1	1.60	71.3
Labour	days/mu	310	8.29	6.90	0.80	58.9
Water	m^3/mu	308	483	220	53.3	1420
Fertilizer	jin/mu	312	208	77.9	33.5	626
Seed	jin/mu	309	74.8	42.1	7.67	381
Age of head	years	315	46.4	10.2	23	78
Education of head	years	314	7.52	3.51	0	15
Total production value	RMB/mu	302	33.3	33.2	0.5	256.5

Note: 1 jin = 0.5 kg.

of the surveyed households equals 1.3 ha, about twice the average size of landholdings in rural China (which equals 0.6 ha according to the 2006 Agricultural Census). There exists considerable variation in landholding sizes, ranging from 0.1 ha for the smallest holding to 4.8 ha for the largest one. Average irrigation water use equals 483 m^3/mu. It varies from 53.3 to 1420 m^3/mu in the sample. Fertilizer use is high, like in many parts of rural China with predominantly irrigated agriculture. The average fertilizer use for the households in our sample amounts to 1560 kg/ha.

Table 1 According to the Minle County Statistical Yearbook 2009, the amount of rainfall during May-August 2009 was equal to 218.3 mm, with the largest amount of rainfall in August: 107.6 mm. Precipitation during the survey year is considered as average by the WMB of Minle County.

5. Water allocation and water transactions in Minle County

Out of the 315 households that we interviewed in the survey, 15 (4.8%) answered that they traded water in 2009. As mentioned above, none of the households interviewed in the baseline survey covering the year 2007 answered that they traded water. The 15 farm households engaged in water transactions in our study are located in nine different villages[7] in six different townships. Among these 15 households, seven are living in one irrigation area, the Hongshuihe irrigation area. With 105 of the 315 interviewed households living in the Hongshuihe area, this means that 6.7% of the interviewed households in that area answered that they traded water in 2009.

These data may be compared with those collected in an earlier study on tradable water rights in Zhangye City reported in Zhang et al. (2009). In that study, survey data covering the year 2003 were collected in five different irrigation areas (out of the 25 main irrigation areas in Zhangye City). Only one of those irrigation areas, Hongshuihe, is located in Minle County; the other four are located in other counties. Zhang et al. (2009) find no water exchanges in the four irrigation areas where there are groundwater sources, and a very limited number of water exchanges in the Hongshuihe irrigation area, where use of groundwater is not a realistic alternative due to the high pumping costs involved. Among the 380 households in the Hongshuihe irrigation area interviewed in their survey, five households traded water with other households. All transactions took place within the own village, and against payment. The average price was 0.025 USD/m^3 (or 0.20 RMB/m^3), while the average traded quantity amounted to 123 m^3.

Table 2 summarizes the trend in water transactions in the Hongshuihe irrigation area based on Zhang et al. (2009) and our two surveys. The data suggest a slightly increasing trend over time, but overall the percentage of households involved in water transactions remains very small.

Table 2
Water transactions in Hongshuihe irrigation area in 2003, 2007 and 2009.

	2003	2007	2009
Number of households interviewed	380	105	105
Number of households with water transactions	5	0	7
Percentage of households with water transactions	1.3	0	6.7

Sources: Zhang et al. (2009) for 2003; our surveys for 2007 and 2009

Water transactions are closely related to land rental transactions among households, since rented land also needs water[8]. When land is being rented out to other households, the water rights belonging to that land are normally part of the same deal. In our analysis we disregard these so-called long term trades, as defined by Zhang et al. (2009), consisting of water and land use rights that are being transferred together. For the purpose of our analysis it is water transfers without parallel land transfers that matters.

Even though the number of observations on water transactions is rather limited, and is insufficient to do any meaningful statistical analyses, a closer look at the available information on these exchanges may provide some useful insights. Table 3 provides more detailed information about the water transactions undertaken by each of the 15 households that were involved in water transfers in 2009. As can be seen from the table, 12 out of the 15 households that transferred water were actually swapping water without payments. That is to say, a household received an amount of water from another household in one round of irrigation and returned the same amount of water in another round, or even within the same round. Such water swaps normally occur between households that are very familiar with each other. As discussed in Section 2, such (non-market) reciprocal water use arrangements are very similar to labour-sharing arrangements that are frequently observed in peasant agriculture. The quantities of water that were exchanged in this way varied from 10 to 540 m^3, with an average of 280 m^3.

Trading through water markets is almost non-existent. Two of the 15 households bought water from another household (at a price of 0.1 RMB/m^3, almost equal to the fee of 0.094 RMB/m^3 paid for the allocated water) in one irrigation round in 2009, and sold the same quantity of water (100 and 150 m^3, respectively) to the same household at the same price in another irrigation round in 2009. So in fact they were also swapping water, but against a fixed payment. Only one household that swapped water with another household also bought a large quantity of water (3000 m^3) later in the season at a price of 0.2 RMB/m^3. And finally there was one household that received 900 m^3 of water without payment in 2009 and also bought some water (100 m^3) at a price of 0.16 RMB/m^3 early in the year.

[7] The nine villages (and the number of households involved) are: Yangjiajuan (2), Wubacun (1), Erzhaicun (1), Yushumiao (2), Mazhuangcun (2), Wujiazhuang (2), Sanpucun (1), Wulangcun (3) and Zhujiangzhuang (2).

[8] Out of the 315 households in our sample, 135 households (i.e. 43%) were involved in land transfers in the year 2009.

Table 3
Traded water quantities and prices in Minle County, 2009.

Household	Atlantic potatoes grower	Direction	Quantity (m^3)	Price (RMB/m^3)	Time	Direction	Quantity (m^3)	Price (RMB/m^3)	Time
1	no	in	150	0	NA	Out	150	0	NA
2	yes	in	440	0	12 June	Out	440	0	12 July
3	no	in	10	0	April	Out	10	0	June
4	yes	in	100	0.1	July	Out	100	0.1	August
5	no	out	350	0	August	In	350	0	September
6	yes	in	240	0	12 June	Out	240	0	17 June
		in	3000	0.2	20 Sept.				
7	yes	in	400	0	Early July	Out	400	0	End July
8	yes	out	150	0.1	May	In	150	0.1	June
9	yes	in	250	0	May	Out	250	0	May
10	no	in	25	0	3 June	Out	25	0	10 June
11	yes	in	500	0	May	Out	500	0	May
12	yes	in	350	0	August	Out	350	0	2010
13	yes	in	540	0	20 June	Out	540	0	20 Sept.
14	no	in	900	0	June	In	100	1.6	January
15	yes	in	100	0	5 June	Out	100	0	20 June

NA = not available.

This raises the question why almost all of the (rather limited number of) water transactions that we observed took the form of reciprocal water sharing arrangements. By exchanging water, both parties can benefit from seasonal variations in water values. But that would also be the case if water transactions take place through a market. As suggested by Tu and Bulte (2010), levels of general and local trust may play a role in deciding to use either market or non-market exchanges. Although farmers in our research area possess tradable water use rights, they do not possess certificates of those rights. Trading of water may therefore easily cause conflicts between buyers and sellers. The perceived risks of water transactions depend on the extent to which both sides believe that the other side can be trusted.

The baseline survey carried out in May 2008 contained questions about trust. Respondents were asked to indicate their trust level to 10 different groups (parents, brothers/sisters, children, other relatives, local officials, classmates/peers, neighbours, familiar (known) people, staff in companies, strangers), using a scale from 0 (totally distrust) to 1 (fully trust). Ma (2013) performed factor analysis, using the standard method of principal-component factors, to analyse the answers to these questions. Based on rotated factor loadings (pattern matrix), he distinguished between kinship trust (trust to parents, brothers/sisters and children), trust towards known people (the trust towards classmates/peers, neighbours and familiar (known) people) and trust towards strangers (trust towards staff in companies and strangers). The observed average levels of trust equal 0.96 for kinship trust, 0.79 for trust towards known people, and only 0.44 for trust towards strangers. Ma (2013) uses these results to explain the segmented and underdeveloped land rental market in the region.[9] Our finding that the limited number of water transaction in the region are reciprocal transactions between households that are very familiar with each other, while impersonal market transactions are virtual absent, may be explained in a similar vain.

What role did the establishment of the potato processing company and the priority given to Atlantic potatoes in water allocation play in promoting these water exchanges? Among the 15 households who were involved in water transactions in 2009, ten households (i.e. 2/3) grew Atlantic potatoes that were supplied to the new company. Out of the 315 households that we interviewed, 105 (i.e. only 1/3) grew Atlantic potatoes in 2009. Hence, Atlantic potatoes growers were relatively more involved in water transactions than other farmers.

As mentioned before, Atlantic potatoes require a relatively large amount of water, but need it later in the season. They do not need water during the first irrigation round (early May), when the seedlings are still small, but receive water during the other irrigation rounds and extra irrigation rounds later in the year. As discussed in Section 2, water users have an incentive to trade water whenever the marginal net benefits of water differ between water users. For Atlantic potatoes growers, the marginal benefits of water are expected to be relatively low during the first irrigation round and much higher during the later rounds. In our data, however, we hardly find any Atlantic potatoes growers who provide water to other households during the first round (early May) and obtain water in return during a later irrigation round (see Table 3). The spring period is a very dry season in Minle County, and hence there is a high demand for applying water to most crops during the first irrigation round. It may therefore be assumed that the marginal benefit of water is very high for all farmers during the first irrigation round, and no water transactions take place. Later in the year, when there is more precipitation, the marginal benefits of irrigation water become lower. The water that Atlantic potatoes farmers receive during extra irrigation rounds may not always fit the growing requirements of the crop. Hence, it makes sense for them to swap part of this additional water with other households in their own WUG or WUA.

Why did only ten of the Atlantic potatoes growers exchange water in 2009, and the other 95 did not? A number of factors may explain the low incidence of water transactions. Firstly, knowledge may be an important factor. Households with better-educated heads may be more efficient farmers that obtain higher marginal net benefits of water. The average education level of the head of the household for all the households who planted Atlantic potatoes in 2009 and did not exchange water is 7.95 years, while that of Atlantic potatoes growers who exchanged water in 2009 is 8.50 years on average (see Table 4). But the difference is not statistically significant.

Secondly, a larger area planted with Atlantic potatoes results in the allocation of more water due to the water allocation priority policy, and may induce water selling. It may also induce water swapping if the additional water is delivered at times when the marginal benefits it provides to Atlantic potatoes farmers are lower than those in other irrigation rounds and are lower than the marginal benefits it offers to other farmers during the same round of irrigation. In 2009, the size of the area planted with Atlantic potatoes for the ten Atlantic potatoes growers that exchanged water

[9] The regression results presented in Ma (2013) show that trust towards known people has a significant positive effect on the probability and intensity of land renting and on the use of informal rental contracts.

Table 4
Characteristics of Atlantic potatoes growers.

	Education of head (years)		Arable land (mu)		Atlantic potatoes area (mu)		WUR land (mu)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Atlantic potatoes growers	8.00	2.42	20.0	11.2	0.92	0.657	15.3	11.7
Exchanging water	8.50	2.97	22.0	12.4	1.04	0.847	20.0**	7.0
Others	7.95	2.91	19.8	11.1	0.91	0.638	14.8**	7.6
Whole sample	7.49	3.51	19.6	12.5	0.31	0.575	13.8	7.8

** Indicates that the difference between the group means is statistically significant at the 5% testing level. The differences between the mean values of the other variables are not significant at the 10% level for farmers exchanging water and other Atlantic potatoes growers.

was 1.04 mu while it was 0.91 mu for the other farm households growing Atlantic potatoes (Table 4). But again the difference is not statistically significant. Likewise, the difference in the total arable land size did not differ significantly between the two groups in 2009. One important aspect that differed significantly (at a 5% testing level) was the size of the WUR land (see the last two columns of Table 4). Atlantic potatoes farmers who exchanged water had significantly more WUR land (22.0 mu on average) than other Atlantic potatoes farmers (14.8 mu on average). As mentioned in Section 3, water is allocated to crops other than Atlantic potatoes according to their WUR area. Therefore, households owning land with a large WUR area receive more water for irrigating all their crops than households with relatively small WUR areas, and may find it profitable to swap part of this water with other households to make it fit better to their crop growing requirements.

An important aspect of the functioning of water markets is the pricing of water. Under a proper water trading scheme, the water price should reflect its marginal value to buyers and sellers. In the absence of transaction costs, each unit of water will be worth the same at the margin to each agent after the exchange. For this to happen, water users should be free to set their own water prices. However, water prices are not fully market determined in Minle County. According to the Bureau of Water Resource Management in Zhangye City, the prices of exchanged water are not allowed to exceed 0.3 RMB/m^3. If a household charges a higher price for its WUR, the WUR allocated to that household can be withdrawn by the local government.

High transaction costs may also be an important obstacle to the development of water markets (see Section 2). Transaction costs faced by households interested in trading water include time and costs involved in acquiring information on possible water trading procedures, in searching for households willing to sell or buy water, in negotiating the conditions of the water transfer, and in monitoring and enforcing water transfers (see also Zhang et al., 2009). As discussed above, trust may play an important role in this respect. Low levels of trust result in relatively high transaction costs. The water exchanges that we observed in our survey all occurred between relatives or neighbours, where levels of trust tend to be high.

Information that we obtained during field visits and informal talks with farmers provides additional insights into the reasons for the almost complete absence of market transactions. In the first place, the amount of water allocated to households is often considered insufficient for irrigating all the crops that they planted, let alone that they would have redundant water for selling. This implies that it is difficult for households willing to buy water to find potential sellers, given the prevailing water price ceiling. In the second place, if there exist large differences in marginal benefits of water between farm households, the incentives for trading water will be large. In our research area, however, differences in marginal benefits between farm households may be relatively small. Irrigation requirements mean that farmers need to tune their crop choice and management decisions with other households within the same WUGs and WUAs. As a result, farmers within the same WUA tend to grow similar crops with similar (planting and irrigation) technologies.

Costs of obtaining (reliable) information are an important element of transaction costs. In our survey held in May 2010 we asked questions about farmers' understanding of the tradability of their WUR in 2007 and 2009. Although the exchange of WUR is permitted since 2002 in this area, only 9.8% of the interviewed households were aware that they could buy or sell water against payment, while 24.1% realized that they were allowed to swap water use rights in 2007. In 2009, these percentages were only slightly higher: 10.8% thought that they were allowed to buy or sell water, and 27.9% mentioned that they were allowed to swap water (Table 5).[10] In conclusion, these data suggest that information asymmetry between the government and water users may be one of the main obstacles to water trading in this region.

As mentioned above, the price that farmers can charge for water should not exceed 0.3 RMB/m^3. Theoretically, the price constraint is expected to affect water market transactions by limiting the supply of water and increasing its demand. However, in our survey we found that only six respondents were aware of the upper limit set by the government. Therefore, the price limit does not seem to constrain market exchanges of WUR in this case.

Given the current low water price and limited availability of water, the marginal benefits of water may exceed the actual water price (0.09 RMB/m^3 on average) for many farmers. Zhang (2013) estimated crop-specific marginal water values, based on a system of crop production functions, for the 315 farm households that we interviewed in Minle County. The estimated marginal values equal 0.046 RMB/m^3 for grains, and 0.266, 0.543 and 0.567 RMB/m^3 for Atlantic potatoes, other potatoes and other cash crops, respectively. In other words, crop-specific marginal values are far from being equal and there remains much scope for gains to be obtained from water trade, especially between grain-oriented and cash crop oriented farmers.

We can conclude that the low water price, the lack of appropriate information and the low level of trust towards unknown persons seem to limit the functioning of the water market, even though a tradable WUR system has been introduced through the pilot project and despite the fact that the establishment of the large potato processing company has created more economic incentives for water trading. If farmers would be well-informed that they are allowed to exchange WUR, if they would be free in choosing a water price without any restriction, and if appropriate conflict resolution mechanisms would be in place, more farmers will be expected to sell or buy water at prices that most likely will exceed the current fixed water price and in some cases perhaps even the current ceiling on the water price.

[10] Most households that answered positively to these questions for the year 2007 also gave a positive response for the year 2009: 9.2% (buying or selling) and 21.3% (swapping) respectively. In addition, the majority of the households that answered positively to the question about buying or selling also answered positively to the question about swapping water: 8.3% for the year 2007 and 8.6% for the year 2009.

Table 5
Farmers' understanding of water exchange rights.

Are you allowed to swap water with others?					
2007			2009		
Yes (%)	No (%)	No idea (%)	Yes (%)	No (%)	No idea (%)
24.1	52.4	23.5	27.9	48.9	23.2
Are you allowed to buy or sell water?					
Yes (%)	No (%)	No idea (%)	Yes (%)	No (%)	No idea (%)
9.8	64.4	25.7	10.8	62.5	26.7

6. Conclusion

In this study we examine irrigation water exchanges in a region in China where households possess tradable water use rights, where a major agro-processing company has recently been established, and where the local government intervenes in the allocation of water to stimulate farmers to grow a cash crop for that company. Despite these favourable enabling and driving factors, we find that water market transactions are virtually absent. Instead, we observe that reciprocal water use arrangements (water swaps) have emerged at a limited scale.

The case crop stimulated by the new company and the local government, Atlantic potatoes, needs a relatively large amount of water for growing, but it needs it later in the season than many other crops grown in the region. The water swaps that we observed take place between relatives or neighbours, with usually no payments involved, and seems to be meant to improve the timing of water applications to crops with different seasonal water requirements.

A more detailed analysis of the observed water exchanges shows that a relatively large share of Atlantic potatoes farmers are involved, and that these farmers tend to have better access to irrigation water than other farmers. We further argue that high transaction costs, resulting from existing information asymmetry between the government and farmers and from low levels of trust in unknown people, severely limit the trading of water. In 2009 only 27.9% of the interviewed households was aware that they were allowed to swap water with others, while only 10.8% knew that they were allowed to buy or sell water against payment. Out of these, only a minority (1.9% of the entire sample) knew the maximum price they are allowed to charge in trading water. The few paid transaction that we observed in our survey took place at prices that were close to the price set by the government for standard water allocations to farmers. High levels of trust towards kinship and known people as compared to unknown people seem to play a role in our finding that the few water transactions that we observe in the region consist almost entirely of water swaps, a non-market institution similar to reciprocal labour sharing arrangements, instead of market transactions. Hence, we can conclude that factors other than an improvement in the output market (such as producer ignorance, centrally set prices, trust) need to be considered, if improvement in the market for irrigation water is to occur.

More research is needed into the root causes of these problems, particularly the information asymmetry, in order to come up with policy recommendations on ways to deal with this problems. An important potential explanatory factor that needs to be taken into account in such follow-up research is the extent to which local government self-interests, particularly the workload that promotion of water trading brings to bureaucrats, plays a role in the currently existing information asymmetry between the government and local farmers.

Other issues that need more attention are how water transaction with unknown people can be promoted, given the prevailing low levels of trust, and to what extent credit constraints play a role in farmers opting for using water swaps instead of market transactions. A recent study on tenure security, trust and land rental market development in rural China, concludes that improvements in the rural legislative system and its implementation may reduce the costs borne by farm households in protecting their land rights via formal legal means, such as official meditation and arbitration and going to the court (Ma, 2013, Chapter 5). The development of water markets based on impersonal transactions is likewise expected to gain from a better protection of water use rights through improvements in the legal system and its implementation. With respect to credit constraints, the current literature suggests that they can be an important driving force of reciprocal labour-sharing arrangements. Given that most water swaps that we observed in our household survey in Minle County took place without payments, credit constraints may also be an important driving factor. Our survey, however, did not include questions that would allow us to examine this issue.

Given the rather limited number of farmers involved in water transactions in the research area of this study, further research in this field should preferably use a dataset with sufficient observations on water transactions to perform meaningful statistical analyses in order to test the tentative conclusions that we draw about factors driving the development of the water market. Such research should preferably be carried out for multiple years, and use appropriate methods to correct for the potential impact of time-dependent factors, like variations in rainfall and water availability and changes in the (global, national and regional) economic environment, which we could not do in our study.

Creating proper institutions for the development of water markets, reducing transaction costs involved in using water markets (particularly through provision of more adequate information) and removing existing restrictions on water prices are important preconditions for improving economic efficiency of water use. In the implementation of these measures, due attention should be given to potential negative effects on the achievement of other important policy goals such as reduced income inequality and maintenance of grain self-sufficiency. If such negative effects are found to occur, appropriate counteracting measures may need to be undertaken without compromising the goal of achieving more efficient water use in irrigated agriculture.

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