Agricultural Water Management 103 (2012) 54–61

Contents lists available at SciVerse ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

A simulation of water markets with transaction costs

Yahua Wang*

School of Public Policy and Management, Tsinghua University, Beijing 100084, China

ARTICLE INFO

Article history:
Received 31 January 2011
Accepted 19 October 2011
Available online 21 November 2011

Keywords:
Water markets
Transaction costs
Agricultural water use
Water saving
Yellow River
China

ABSTRACT

Most theorists regard transaction costs as one of the key lenses to understand the water rights market. This paper proposes a theoretical model of water rights trading with transaction costs according to the idea of costs minimization. Applying the model to the Yellow River Basin (YRB), we evaluate the potential of investment savings from introducing the trans-jurisdictional water market to achieve the water-saving targets of agricultural and industrial sectors. The simulation results confirm that the potential benefits from the trans-jurisdictional water markets are considerable in the condition of zero transaction costs, and the benefits are inclined to increase with the decrease of transaction costs. The potential of trading water between the agricultural sector and the industrial sector is much larger than within the agricultural sector. The simulation also implies that the agricultural sector is more sensitive to transaction costs than the industrial sector, and thus priority should be given to reduce the transaction costs paid by the agricultural sector in the institutional design of inter-sectoral water transfers.

1. Introduction

Agriculture is the largest water user in Northern China, consuming 74.4% of total water use in 2008 (MWR, 2008). With increased water scarcity, the competition for the limited water resources has been intensified between agriculture and the municipal and industrial sectors. At the same time, irrigation water use efficiency is still low, and is accused to be responsible for the current water stress (Cai, 2008). It is believed that water scarcity has become an increasing constraint to food security and sustainable development of agriculture in Northern China (Yang et al., 2003; Huang et al., 2009; Du et al., 2010).

To address the serious problem of water scarcity, the Chinese government has reformed the water management system over the past decade, with one key change being the "development of a water rights system for allocating entitlements to water and allowing for the transfer of water rights" (Sun, 2009). The tradable water rights system, founded 10 years ago, is becoming important to achieve greater economic efficiency in water resources (Zhang and Zhang, 2008). In practice, several pilot projects of water rights transfer have been introduced in Northern China, one of which lies in the Yellow River Basin (YRB).

Located in the arid and semi-arid zones of Northern China, the YRB supplies the water for 140 million inhabitants and 15 million hectares of agricultural land. With the massive social and economic development, water withdrawal and consumptive use increased significantly in the 1980s and 1990s. In the 1970s, seasonal dry ups emerged in the downstream. During the 1990s, the frequency and the length of the seasonal dry ups increased substantially and brought serious consequences (Yang and Jia, 2008).

The break in river flow drew a broad public concern and the government was urged to take actions to resolve the problem. From 1999, many measures have been adopted to deal with the dry ups, including seriously implementing the Yellow River Water Allocation Plan, which was issued by the State Council in 1987 and allocated water resources among the 10 provinces that use water of the river. From then on, a system of total amount control of regional water use in terms of the water rights system has been established gradually in the basin (Shen and Speed, 2009).

Several riparian provinces including the Inner Mongolia Autonomous Region and the Ningxia Hui Autonomous Region in the upstream of the YRB, have exceeded the water quota allocated when the Yellow River Water Allocation Plan was issued. Since the implementation of total amount control of regional water use from the end of the 1990s, new demand for industrial water use has had to seek new sources of water. One option is to access water resources from agricultural sector, since it is widely believed that there is excessive irrigation in Ningxia and Inner Mongolia and the "increase in the agricultural water use efficiency is the key approach to mitigate water shortages and to reduce environmental problems" (Deng et al., 2004). Therefore, it becomes a natural choice to "reallocate water from agriculture to industry through increasing irrigation efficiency, generally through engineering measures, such as canal lining" (Ringler et al., 2010).

The water rights transfers between agriculture and industry in the upper reaches of the YRB have been encouraged by the

* Tel.: +86 10 62783923; fax: +86 10 62772199.
E-mail address: wangyahua@tsinghua.edu.cn

0378-3774/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.agwat.2011.10.017

Chinese government, though there are still considerable challenges regarding the implementation (Wang and Zhang, 2009). It is basically treated as a win-win game, not only solving the water demand of new industries, but also promoting the water efficiency of agricultural water use. To date more than two dozen such cases of water rights transfer has occurred in Inner Mongolia and Ningxia, with the common characteristic of "investing in water saving and transferring water rights".

Currently, the water rights transfer in the upstream of the YRB usually happens between industrial projects and adjacent irrigation districts in the same municipal district. Trans-jurisdictional water transfer is a rare occurrence between the different municipal districts within one province, not to mention the transfer between provinces (YRCC, 2008).

However, as the cost of saving water varies across different irrigation districts, in theory, the irrigation districts which present with the lowest water saving costs should be the most attractive for industries to purchase, rather than adjacent irrigation districts, which may not have the lowest water saving costs. Obviously, the key variable restricting industries from buying water from non-adjacent areas is the transaction costs of trans-jurisdictional water transfers. This paper makes an attempt to evaluate the potential benefits of the trans-jurisdictional water markets, and the effect of transaction costs on the outcomes of the trans-jurisdictional water transfers in the YRB.

2. Literature review

Since the early 1980s when the water rights markets were increasingly introduced worldwide, the empirical studies around water rights trading have been gradually developed (Simpson and Ringskog, 1997). The establishment of tradable water rights were hoped to "play an important role in improving the efficiency, equity, and sustainability of water use in developing countries" (Rosegrant and Binswanger, 1994). Although the water rights market in theory has a lot of potential revenue, in practice "it is not easy for many countries or regions to establish open water markets due to the existence of various barriers" (Saliba and Bush, 1987; Bauer, 1997, 2004; Pigram, 1993; Easter et al., 1999; Zhang, 2007). Water is a field beset with the classic problems of market failure (Perry et al., 1997). A number of practical issues including market forces, technological conditions, risks and uncertainties, and transaction costs may offset the potential cost-effectiveness from water rights markets.

Transaction costs, as an important factor in restraining water rights trading, has been emphasized in many studies (Colby, 1990; MacDonnell, 1990; Brajer et al., 1989; Slaughter, 2009). Hearne and Easter (1997) pointed out that the operational difficulties of the trading system of water rights are rooted in the existence of transaction costs and third-party effects. Hellegers and Perry (2006) argued that "transaction costs could be large enough to block the introduction of market pricing and tradable water rights in many cases". Transaction costs, including information costs, bargaining and decision-making costs, enforcement costs and other costs associated with contracts are increasingly regarded as the key influence on the performance and institutional choice of the water rights markets.

Many scholars, such as Nickum and Easter (1991), Lund (1993), Easter et al. (1998), Challen (2000), and Carey et al. (2002) have explored the effects of transaction costs on water rights markets from different perspectives. Some literature has attempted to simulate the effects of transaction costs through modeling water trading. For example, Takayama and Judge (1971) introduced a spatial equilibrium model of water trades to demonstrate the effects of transaction costs on outcomes from market allocation; Garrido (2000) proposed a mathematical programming model to simulate the water market within the agricultural sector in Spain. According to the conclusions of the existing studies, the role of transaction costs is to reduce the possibility of water trading and market scale, and increase the price dispersion.

As an emerging phenomenon in China, the water rights market has received significant attention by policymakers and researchers. However, it is still unclear in China "how water trade should be established and implemented and what the potential benefits from water trade are" (Wang and Zhang, 2009). Heaney et al. (2006) used a production-function approach to assess the benefits of water reallocation in the YRB. According to this study, the total benefits are estimated to be 1 billion Yuan (US$0.15 billion/year) per year with reallocation chiefly occurring from the midstream to the downstream area, which represents an increase in the value of agricultural production of around 1.8 percent. But this estimation is based on the assumption of a free market without considering the effects of transaction costs, and the trading is only within agricultural water use.

Taking a broader survey of previous research, the basic modeling idea is to maximize the benefits from water trading. The usual model is to deduct the costs from the benefits of water trading, and then solve optimization problems under the constrained conditions. This paper proposes a different idea for modeling water trading, which is by minimizing the costs under the constrained conditions, to examine the cost effectiveness brought by the water rights trading. This type of model has practical significance for water management with the cap and trade system such as the water resources management in the YRB (Speed, 2009). For example, the water uses of some provinces have exceeded the water quota allocated in the YRB. These provinces are facing the task of reducing the amount of water to the quota allocated in the way of cost-effectiveness. The whole river basin faces the problem of how to achieve control with minimum costs.

In contrast to the research on water trading, the usual idea of modeling to minimize the costs under the constrained conditions is used in the field of trading emission permits. This is because the main problem for pollution control is how to reduce emission with lower costs to achieve the control of total emission permits, which is a typical cap and trade system. In the literature of this field, there are many studies on the impact that transaction costs bring to the emission permits market. For instance, Stavins (1995) proposed a model of permit trading with transaction costs; then Montero (1997) developed "theoretical and numerical models that include transaction costs and uncertainty to show their effects on market performance"; and Cason and Gangadharan (2003) used "laboratory experiments to study how transaction costs interact with permit allocations to determine the cost-effectiveness of emissions abatement".

This paper brings forward a theoretical model of water rights trading with transaction costs, based on the literature of trading emission permits, especially Stavins' (1995) work. In the following, we adopt the method of numerical analysis to simulate the effects of transaction costs on water rights market. The simulations results in different scenarios are reported and policy implications are discussed.

3. A model of water rights trading with transaction costs

3.1. Theoretical model

We consider a water trading market with N actors (water users), and define symbols for each actor i as follows:

u_i: amount of current water use;