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Sharing a river: Potential performance of a water bank for reallocating irrigation water

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ABSTRACT

This paper presents an *ex-ante* policy analysis of the implementation of a publicly run active water bank operating at the basin level designed to temporarily reallocate water resources between farmers considering different scenarios of reduced water availability (cyclical scarcity due to droughts). For this purpose, the Guadalquivir River Basin, located in southern Spain, is used as a case study. Fifteen representative farm types were considered to simulate water trading through public tender for purchasing and selling temporary water rights. The model is built at the basin level to estimate the aggregate demand and supply curves to establish expected exchange prices, volumes of water traded, enhancement in economic efficiency and improvement in rural development as measured by employment generation. The simulation results show that the proposed water bank encourages water transfers from 19% of the total water used in the case of a moderate drought to almost 40% in the case of an extreme drought, significantly reducing the economic and labor demand losses due to water shortages. The public water agency can recover all of the incurred water bank operation costs by implementing a €0.01/m^3 price differential between purchase and sale prices without meaningfully affecting the performance of the water bank. Thus, we conclude that the implementation of this kind of water bank during droughts would be useful in mitigating negative effects of droughts. Thus, policymakers are encouraged to create water banks as an effective instrument to cope with droughts.

1. Introduction

Climate change is causing a progressive reduction in water availability in many semiarid regions worldwide, as is the case in the Mediterranean region (IPCC, 2014). This fact, combined with population growth and the rising demand for food (and ultimately for irrigation water), is a primary reason for why water resources have become scarcer in these regions throughout the past few decades. In addition to the resulting increase in structural water scarcity, climate change is also producing more frequent and severe drought periods, resulting in more recurrent and intense episodes of cyclical water scarcity.

Due to the competitive advantages of irrigated versus rain-fed agriculture in these semiarid regions, the primary solution that has been advanced by public and private initiatives has been to increase water availability by building dams and other water infrastructure. This process, commonly known as supply-side water policy, was implemented during the 20th century, during which a great amount of water infrastructure was built. However, there is evidence from around the world that this kind of water policy cannot be further developed in these regions since in many river basins, new increases in water availability are technically infeasible or economically unaffordable, which is a situation called 'basin closure' (Molle et al., 2010). When basin development reaches the closure stage, any new water demand must be satisfied by reducing other existing water use. Under these circumstances, demand-side water policy instruments such as water trading instruments are considered to be the most suitable solutions to provide the necessary flexibility in water rights systems, allowing for a more efficient reallocation of water resources. Thus, water trading instruments are useful tools for managing both cyclical and structural scarcity.

Water trading instruments encompass a full range of institutions that facilitate voluntary exchanges of water between users (Delacámara et al., 2015). These markets can take different forms depending on key variables that define their operational rules (Griffin, 2016), such as the rights being traded (permanent rights, temporary rights, and options on temporary rights) or the parties allowed to trade (sellers and buyers). Regarding the latter, it is important to distinguish between 'water markets' that involve

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only private parties, where buyers and sellers interact directly to negotiate the terms of water rights transfers (sometimes with the participation of intermediaries or brokers), and the so-called 'water banks', which operate in a more institutionalized context where an administrative agency (public or private) acts as a necessary intermediary in the trading of rights (Rey et al., 2014).

Water banks are intermediaries that centralize the purchases and sales of water rights, acting between buyers and sellers (Spulber and Sabbaghi, 1994). These banks are typically managed by a public institution (e.g., water agencies). In such cases, water is transferred under the supervision of the public administration, which verifies that the water transactions fulfil all legal requirements, sometimes including constraints that are linked to environmental and social criteria (Garrido et al., 2012). These institutional arrangements are designed to cope with both structural scarcity (permanent exchange of water rights) and with cyclical scarcity (temporary water rights transfers).

Montilla-López et al. (2016) reviewed international experiences with water banks and demonstrated the advantages of this instrument over other kinds of water trading instruments (i.e., water markets). More concretely, the authors show how water banks allow for a more flexible and efficient reallocation of water resources because they facilitate contact and negotiation between buyers and sellers and they improve transparency by providing public information on prices and quantities, resulting in lower trade operation transaction costs (Garrick et al., 2013), thus boosting market activity and fostering a more efficient use of water resources (Grafton et al., 2011). Furthermore, water banks encourage government oversight of environmental and social externalities that arise from water trading. They also allow operations with environmental purposes (public offers to purchase rights without subsequent reallocation) in order to increase river flows, restore overexploited groundwater bodies, etc. (Clifford et al., 2004).

Numerous empirical works have focused on water markets worldwide, and many have analyzed the potential and actual performance of this instrument (Easter and Huang, 2014; Maestu, 2013). For *ex-ante* analyzes of the performance of water markets, simulation models that are developed with mathematical programming are typically used (e.g., Gómez-Limón and Martínez, 2006; Garrido and Calatrava, 2009; Qureshi et al., 2009; Kahil et al., 2015), providing evidence of the potential impacts of water markets on the economy (economic efficiency), the environment (water use and other environmental issues) and society (regional development). These studies note that trade of water entitlements (permanent rights) and water allocations (temporary rights) improves the efficiency of water use at the basin level, with farmers typically playing central roles in the process.

Despite these advantages of water banks over other water trading instruments, there is little literature with a similar purpose focused on water banks. The only exceptions worth noting are the works of Qureshi et al. (2007), Mainuddin et al. (2007) and Dixon et al. (2012) in Australia; Medellín-Azuara et al. (2013) in the western United States; and Martínez-Granados and Calatrava (2014) and Pérez-Blanco and Gutiérrez-Martín (2017) in Spain. However, all of these studies simulated water banks that were designed to reduce overall water consumption in over-allocated basins for environmental reasons. Thus, empirical evidence has focused only on water banks that bought water rights in order to restore water balances (known as 'buyback'). None of these works have analyzed the implementation of water banks as instruments for reallocating water rights between productive users (e.g., between irrigators) as an alternative to other kinds of water trading instruments (i.e., water markets). This paper aims to bridge this knowledge gap by simulating the potential performance of a water bank that is designed to reallocate water resources between irrigators to check whether this is really a useful approach for coping with droughts.

Thus, the objective of this work is to perform an *ex-ante* policy analysis of the implementation of water banks that trade temporary water rights (first buying these rights and then selling them to other productive users), accounting for different future reduced water availability scenarios (cyclical scarcity). For this purpose, a simulation model based on mathematical programming is built to estimate the aggregate demand and supply curves to establish the expected exchange prices, volumes of water traded, enhancement in economic efficiency and employment generation. This model was used to simulate the performance of the water bank proposed considering the irrigation sector within the Guadalquivir River Basin (GRB) in southern Spain as an illustrative case study. Although there are no previous modeling exercises that simulate water banks in this basin, there are several empirical studies that analyze the potential performance of water markets using this simulation approach (Garrido, 2000; Arriaza et al., 2002; Calatrava and Garrido, 2005). These previous works would provide a basis for an interesting discussion regarding the implementation of both water trading instruments.

To achieve the abovementioned objective, the remainder of the paper is organized as follows: The next section justifies the type of water bank that is proposed to improve cyclical scarcity management within the irrigation sector as the specific instrument to be simulated. The third section introduces the case of the irrigation sector in the GRB, for which an empirical implementation is developed. Section 4 details the simulation model that was developed to simulate the performance of the water bank that was proposed for enhanced drought management. The results of the simulations are summarized in Section 5. The final section concludes by providing the main insights derived from this study.

2. Water banks for managing drought periods within the irrigation sector

As mentioned above, the term 'water banks' covers a wide variety of institutional designs. Montilla-López et al. (2016) identified a number of different types of water banks, as shown in Table 1.

Having compared the different kinds of water banks, there is no doubt that all designs could be useful in reducing the operational transaction costs for all agents, thus boosting market activity. However, public and active water banks are assumed to improve the management of cyclical and structural water scarcity since they can exercise more effective control over market operations (reducing environmental and social negative externalities). Moreover, considering that the main purpose of the bank proposed is to reallocate water within the agricultural sector during drought periods, it is also evident that the best design for this instrument should consider the water itself (spot market) or temporary water rights (lease market) as assets to be exchanged, and all irrigators in the basin as agents who may potentially participate in market activities (purchases and sales).

In this sense, an active water bank seeks to set the conditions for the purchase and sale of rights for reallocation purposes in order to achieve a balanced market. Thus, the bank should first act as the sole water buyer of water rights (monopsony market) by organizing public water rights purchase offers and subsequently act as the unique water seller (monopoly market) of all the rights that were previously bought by organizing public sale offerings.

To date, there have been many experiences with a number of different water bank designs around the world. Some of these experiences are based on the same type of water bank that is proposed in this paper for *ex-ante* policy analysis, with most in the western states in the US. The most well-known program is likely the Drought Emergency Water Bank that was developed in California in 1991 to improve water management during a cyclical scarcity