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Review

Water Banks: What Have We Learnt from the International Experience?

Nazaret M. Montilla-López *, Carlos Gutiérrez-Martín and José A. Gómez-Limón

Department of Agricultural Economics, University of Córdoba, Campus Rabanales, Ctra. N-IV km 396, Córdoba 14014, Spain; carlos.gutierrez@uco.es (C.G.-M.); jglimon@uco.es (J.A.G.-L.)
* Correspondence: g02molon@uco.es; Tel.: +34-957-218-462

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Abstract: In recent decades, the use of economic instruments has been promoted as a way to improve water demand management, required due to the difficulty of further supply increases. Against this backdrop, this paper analyses the potential of water banks as a type of water market that can provide institutional flexibility in the allocation of water resources among different users. Research has involved an extensive review of the literature, which has allowed us to identify different types of water banks that operate around the world, as well as an analysis of the experiences of water banks implemented to date, in order to assess the performance of this economic instrument in improving water management. This has provided evidence that water banks, if properly implemented, can be a useful tool for improving governance of water resources. Finally, the analysis has enabled us to propose a number of guidelines on how to improve the implementation of water banks in different countries around the world.

Keywords: water policy; water management; economic instruments; water banks; water reallocation

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1. Introduction

Population growth and the resulting demand for food (irrigation) has, over the course of the 20th century, led to a marked increase in global water abstraction and consumption [1]. Moreover, as a result of global warming and climate change, we are witnessing an overall reduction in water availability around the world (structural scarcity), as well as more frequent and more severe drought periods (cyclical scarcity). This is especially true in arid and semi-arid regions [2] such as California, Australia, and Spain, where irrigated agriculture is particularly competitive, and agricultural consumption accounts for up to 80% of total water use.

To date, management strategies to cope with water scarcity have been predominantly based on structural solutions aiming at boosting the total amount of water supplied (increase in reservoir capacity, exploitation of groundwater, or reusing treated wastewater). In mature water economies, however, evidence shows the difficulty of further implementation of this traditional approach to water policy based on supply-side measures [3], for both environmental reasons (almost all usable water resources are already used) and economic ones (the high costs of generating additional water supply). This situation has led to a reorientation in water policy, in order to make it more focused on the efficient reallocation of existing water resources. This is especially important in regions where it is not possible to further expand water supply ("closed" basins) and where the implementation of demand-side measures is, thus, considered a priority. Such measures include economic instruments, such as water pricing, water caps, water markets, and voluntary agreements. These mechanisms provide public authorities with useful tools for solving mismanagement problems through a more efficient reallocation of existing resources, thus mitigating the effect of both structural and cyclical scarcity (water shortages due to droughts) [4,5].

Within this context, this study aims to examine the potential of water banks as an economic instrument for demand-side management in closed basins with environmental sustainability issues (overallocation of resources and deterioration of water bodies) and great uncertainty as to resource availability (growing impact of droughts due to climate change). Accordingly, this study includes a critical analysis of the implementation of water banks around the world in order to examine the advantages and disadvantages of this economic instrument for managing scarcity, environmental issues, and uncertainty regarding water availability. It concludes by providing a number of suggestions for improving the design and implementation of this economic instrument in the sphere of water policy.

To that end, the paper is organized as follows: The following section is dedicated to defining the concept of water banks and identifying different categories. Section 3 describes the key experiences of water banks implemented around the world. Section 4 details the advantages and disadvantages of water banks as an instrument for managing scarcity. Lastly, in light of these experiences, Section 5 concludes by presenting a series of proposals for improving water banks as an instrument to ensure the efficient use of resources across sectors and users, including the environment.

2. Water Banks: Concept and Types

2.1. Water Banks as a Type of Water Market

Economic theory holds that markets are an efficient mechanism for allocating scarce resources in case several stringent conditions are met, including perfect competition, the absence of externalities and no transaction costs, among others (for further details, interested readers can consult any microeconomics handbook, such as Mas-Colell, et al. [6] or Gravelle and Rees [7]). However, these conditions are not usually found in the real world, as is the case with water markets [8,9]. Nevertheless, water markets have been identified as an economic instrument that offers the potential to improve water management in contexts of scarcity, since water market reallocations can lead to more efficient water use and a significant improvement in social welfare [10–12].

The term "water markets" actually refers to a whole range of institutions that facilitate voluntary exchanges of water between users. Indeed, these markets may take different forms depending on their defining variables, including key aspects, such as their legal status (formal and informal), the rights being traded (permanent rights, temporary rights or 'spot markets', and options on temporary rights), or the parties involved (sellers and buyers). With respect to the latter, it is important to distinguish between water markets involving private parties, where buyers and sellers interact directly to negotiate the terms of water rights transfers with the possible involvement of intermediaries or professional brokers, and the so-called water banks, which operate in a more institutionalized context and which, by definition, involve agents who are not, themselves, water users. Thus, a water bank is a market mechanism through which an administrative agency (public or private) acts as an essential intermediary in the trading of rights.

This research paper focuses on the study of water banks, not to be confused with water banking, which is a resource management strategy based on water storage [13]. Indeed, the term 'water banking' refers to depositing water rights, either on paper or an actual volume of water, in a "bank", understood as the water stored in a reservoir, aquifer, or similar. This deposit in the bank provides its holder with access to a wide variety of operations, including deferred resource use and its transfer to other users. Water banking is a well-recognized policy tool to address similar challenges to water banks. Interested readers can consult the case of Arizona water banking as a successful example of this instrument [14].

Delacámara et al. [15] define the concept of a water bank as an institutionalized and centralized process established to facilitate the transfer of water allocated to specific users or uses, to other users and uses. At its simplest, a water bank is a single intermediary acting between buyers and sellers of water rights, whether that transfer is temporary (spot) or permanent. Water banks are typically managed by a public institution (e.g., water agencies). In such cases, water is transferred from certain users to others under the supervision of the public administration, which verifies that the water transactions fulfil all legal requirements, sometimes including constraints linked to environmental and social criteria.

The underlying concept of the water bank is to serve as an institutional mechanism designed to respond to cyclical changes (by means of temporary transfers of water rights) and structural changes (by means of permanent transfers) in resource availability, reducing the transaction costs of operations. Water banks also help boost market activity and improve transparency by facilitating contact between buyers and sellers, as well as providing information on the prices and quantities exchanged. This market system enables interested water users to lease or sell their water rights to any agent (whether user or non-user) willing to lease or purchase them, thus fostering a more efficient resource allocation in both the short and the long run. For all of these reasons, this type of water market is becoming more prevalent in the more mature water economies of the world.

2.2. Water Bank Typology

In practice, the term 'water banks' can cover a wide variety of institutional designs that all adhere to the general concept of water banks described above. Accordingly, we examine below the diverse forms of this kind of water market, based on the experience of water banks implemented to date, and offer an analysis of their principal defining characteristics. This analysis of the characteristic variables of water banks has enabled us to identify a number of different types, which are described below.

First, it should be noted that water banks differ with respect to the nature of the organization responsible for their implementation. In this regard, we can observe the following types:

- *Public water banks* are organized and managed by a public administration, typically one with expertise in the field of water.
- *Private water* banks are organized and managed by means of a private initiative, generally run by non-profit organizations, such as NGOs dedicated to environmental conservation.

A second defining variable of water banks is the type of rights being exchanged. In this regard, we can distinguish between the following types:

- *Permanent water banks*. Rights-holders permanently transfer their water entitlements to the water bank. The rights acquired by the bank can subsequently be reassigned, partly or wholly, to other users (current rights-holders or new users), either by means of acquisition or via a system of free public concession. These banks can be aimed at solving problems associated with structural water scarcity, both economic and environmental in nature [16–18], as is discussed below.
- *Spot or temporary water banks*. These banks act in same way as permanent water banks but with the difference that they deal with temporary transfers of water use rights (usually for an irrigation season) or specific quantities of water (spot). In both cases, the activity is concentrated in periods of drought, and the aim is to mitigate the effects of cyclical shortages [19,20].
- *Option contract banks*. This type of water bank facilitates the exchange of contracts that provide buyers with the option (but not the obligation) to buy water from the seller (the holder of the water rights), in exchange for a certain price or "premium" [21,22]. If the aforementioned option is eventually exercised, the buyer pays additional compensation to the seller, called the "strike price". These contracts allow the buyer to hedge against the risk of not having enough water for their activity, while simultaneously ensuring that the seller does not forfeit the water entitlement (the right to use the water) [23,24].

Water banks can also be categorized according to their purpose. In this regard, we can distinguish between:

- *Water banks for the reallocation of resources as a production input*. Exchanges of rights that enable water banks to reallocate the resource (temporarily or permanently) depending on current and potential suppliers and demanders according to market forces, fostering the transfer of water from lower-value to higher-value uses. These transfers, in the absence of negative externalities, help to make water use more economically efficient [25,26].

- *Water banks for environmental purposes*. These banks work by purchasing rights without subsequently reallocating them [27]. This type of bank, thus, provides a solution to environmental problems stemming from both structural water shortages (addressing overallocation of basin resources by purchasing permanent rights) and cyclical shortages (tackling low water flows in the dry season by purchasing temporary rights).
- *Water banks for managing risk related to water availability*. Climate and hydrological uncertainty inherent to water management causes interannual variability of resource provision. This exposes users to significant risk, and as a result they do not make economically-efficient decisions [28]. In order to minimize sub-optimal decisions and improve water-use efficiency, these banks work by negotiating water options contracts. This helps to improve supply security for the buyers of water options contracts (by reducing supply security for the sellers of such contracts), thereby enabling an effective transfer of risk between users with different levels of risk aversion [23,24].

Lastly, focusing on management strategy allows us to differentiate between:

- *Active water banks*. Those where the managers of the bank adopt a proactive strategy as "market makers", buying water rights out of the bank's own budget, and subsequently attempting to sell them to potentially interested users. In this regard, the aim of the water bank management is to achieve a balanced market, by trying to ensure that the sum of purchases and sales does not yield a net cost (the amount spent on purchases should equal revenue from sales), or that said cost does not exceed a maximum budgeted for this purpose. It should be noted that, in these cases, the bank administrator is the one who sets the conditions for the purchase and sale of rights (or options), and these banks, thus, become a type of monopolistic market with a one-way trading system [29]. As such, the bank first acts as the sole buyer of water rights or options (monopsony through public purchase tenders) and then, in turn, becomes the sole vendor of such rights or options (monopoly through public sale offerings). The purchasing system can vary depending on the nature of the public offerings. The bank may: (i) establish the maximum amount of net purchases (maximum spending budget), whether by means of a fixed price or via auction (successive increments in the purchase price until the total allocated budget has been spent); (ii) fix a maximum volume of water to be acquired, also by means of either budget limits or auction; or (iii) establish a fixed market price for acquisitions, without budgetary constraints or limits on the volumes of water to be purchased. These public offerings may also be differentiated according to whether they are open or restricted; whereas all rights-holders in the territory under the bank's jurisdiction (e.g., a river basin district or users of an aquifer) can voluntarily attend the former, the latter is only for certain types of specifically-authorized users. Similarly, public sale offerings can be differentiated in terms of both price conditions and contract amount, as well as with respect to their open/restricted nature. Active water banks are a useful way of boosting market activity (improving economic efficiency) and exercising more effective control over market operations (reducing externalities and minimizing asymmetrical information about water prices).
- *Passive water banks* limit themselves to facilitating contact between buyers and sellers so that operations can be carried out according to the supply and demand at any particular moment. In these cases, the role of the manager of the bank is simply to act as an intermediary for purchases and sales (broker), either as a clearinghouse or through sealed bid double auctions. In thinner water markets, water banks usually adopt the first approach (clearinghouses), where buyers and sellers reveal their intent to buy and sell, usually posted on bulletin boards, and trades are executed when matching offers and bids are found in terms of quantity and price [30]. Sealed bid double-auctions only take place in more liquid water markets. The offers to buy and sell rights are based on a system similar to the stock market, where the bank provides up-to-date and transparent information (positions or offers to buy and sell). Thus, by matching existing purchase and sales offers, a market clearing price is achieved—the price at which the exchange of all the rights of all those wishing to accept/pay the equilibrium price are cleared [31].

Having analysed the different designs of water banks, and set out a typology based on the existing range of features, it should be noted that not all combinations of defining variables can be found in reality. Indeed, the experiences of banks implemented to date reveal a strong correlation between some of the variables analysed above. For example, it has been observed that banks created to tackle environmental problems arising from the overallocation of rights tend to be active banks dealing in permanent rights. Alternatively, when it comes to minimizing the economic consequences resulting from shortages caused by periodic drought, the water banks set up are public and exchange temporary water rights, either through active or passive management strategies.

3. International Experiences

To date, there have been many experiences of water banks developed around the world. Of particular note are those from the western states of the US (particularly California), the southern states of Australia, and from Spain, where the success of this economic instrument in improving drought management has been clearly demonstrated. It is no coincidence that the most prominent examples of water banks have been developed in these areas, given the similarities between all these territories in terms of climate (Mediterranean climates with high variability in resource availability), hydrology (high water demand and closed basins), and production (highly profitable agricultural uses competing with urban and industrial uses).

The categorization detailed above has enabled us to frame the experiences from around the world according to the different types identified. Before analysing them in detail, a summary of the types of water banks implemented in each territory is shown in Table 1.

Table 1. Water bank experiences.

Type		**California (Federal and State)**	**California (Federal)**	**Idaho (State)**	**Montana (NGO)**	**Colorado (State)**	**Colorado (NGO)**	**New Mexico (State)**	**New Mexico (Private)**	**Texas (State)**	**Texas (NGO)**	**Oregon (State and NGO)**	**Washington (State)**	**Washington (NGO)**	**Australia (Private)**	**Australia (State)**	**Spain (State)**	**Chile (State) [a]**
Rights exchanged	Permanent			X				X		X	X		X	X	X	X	X	
	Temporary or *spot*	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X
	Options		X											X				
Purpose	Resource reallocation	X				X			X	X			X		X		X	X
	Environmental	X		X	X		X	X			X	X	X	X		X	X	
	Risk management		X															
Management strategy	Active	X	X	X	X	X	X	X			X	X	X	X		X	X	
	Passive					X		X	X	X					X			X

Note: [a] Water bank experience in this country is limited to a pilot project.

3.1. Water Banks in California

The recurrent drought episodes that have hit this American state are key to understanding the evolution of its water management policy. In this context, the severe drought that hit the state between 1920 and 1930, combined with a particular set of circumstances including the availability of large federal subsidies, created a political opportunity to develop numerous large-scale water projects in the early to mid-twentieth century. These infrastructures combined to create an extensive hydraulic network connecting all of its counties. For decades, this network allowed those users with the greatest needs, in terms of supply security, to establish a water storage and conveyance infrastructure in the north of the state (where it is wetter) and transfer resources, when necessary, to the south of the state (drier) [32]. From the 1970s onwards, the mature phase of the Californian water economy was reflected in its inability to increase supply. That marked the beginning of the change in water policies, with a focus on new instruments for reallocating existing rights, and the origin of the water markets. The severe drought of 1976–1977 was a crucial moment, driving the Bureau of Reclamation to introduce the first Californian water bank to facilitate water trading between public water entities, especially for urban supply. Over the course of that year, the bank bought 57 Mm^3 (1 Mm^3 = 1 hm^3 = 1 GL = 810.7 acre-feet), of which 52 Mm^3 was subsequently resold [33]. Nevertheless, the main problem facing this first bank was the restriction imposed on private users, which prevented farmers—the main users of water in the state—from accessing the resource [34].

The next major milestone was brought about by the great drought that began in California in 1987. Among the measures implemented in response to this challenge, particularly notable was the Californian state government's creation of the Drought Emergency Water Bank in 1991. This water bank was designed so that the state could act as an agent with an active management strategy, aiming to facilitate temporary transfers of water from the agricultural sector to urban use, at a price set by the state government [33]. The bank's purchase transactions were conducted through various types of one-year contracts [21,35]: in the first type of contract, irrigators sold surface water and agreed to stop cultivating crops; in the second type of contract, farmers sold surface water so that the bank could use it at any point along its watercourse, but they could continue irrigation by pumping groundwater; and in the third type of contract, the bank had access to the reserves held by the seller. This water bank was more successful than anyone had anticipated, producing the largest number of regional exchanges of water resources that had ever taken place in the US up until that point. In total, 1012 Mm^3 of water was acquired, of which 50% came from 348 fallowing contracts (the first type of contract), 32% came from 19 of the second type of contract, and the remaining 18% was purchased via the third type of contract, through which 181 Mm^3 of water was acquired with only four contracts [36]. The water bank subsequently reallocated a total of 488 Mm^3 among higher-value uses; this was water that had previously been purchased at a price of \$0.10/m^3 before being sold at a price of \$0.14/m^3, thereby mitigating the economic losses caused by the drought [23]. Of the total reallocations, 30% (150 Mm^3) was assigned to environmental purposes, in order to increase flows in the Sacramento-San Joaquin delta, and the rest was left unsold [37].

The operations of this water bank were extended in 1992 but with a much lower intensity of market activity, with volumes of water reallocated dropping to 235 Mm^3 [30]. This decrease in the water bank's activity, both in terms of the quantity of water transferred as well as with respect to number of participants, was triggered by the heavy rains that fell in early 1992, which eased the shortage situation and reduced demand on the water bank. Despite the rains of 1992, California's hydrological situation did not return to normal, and in 1994 a new water bank was set up, which bought 272 Mm^3. The forecast of an extremely dry year prompted the State Department of Water Resources to set up an options bank in late 1994. Through this bank, option rights were purchased for a total of 36 Mm^3, at a premium of \$0.003/m^3, and exercised a price in the range of \$0.030–0.035/m^3 [23]. Finally, due to the heavy rains that fell in 1995, which finally brought the drought of previous years to an end, these options contracts were not exercised. In any case, this experience showed that advance planning can be an efficient way to tackle potential droughts, helping to improve water supply security for users with higher water productivity and greater risk aversion [21].

In 2009, attempts were made to set up a new water bank in California to tackle a new drought. This time, however, the experience was unsuccessful because: (i) the institutional instrument design was extremely complex, meaning that only a few operations could be carried out; and (ii) exchanges from water exporting areas were blocked as a result of protests by environmental organizations [38]. This failure highlighted the need to design water banks taking into account not only potential market participants (current water users) but also other stakeholders (civil society organizations) in order to ensure that the bank's exchanges of the resource are considered universally beneficial for all parties involved.

Furthermore, it is worth commenting that although 2014 and 2015 were the two hottest years in the state's recorded history and caused another severe water deficit, no water banks were implemented as an instrument to improve resilience to drought [16].

To sum up the Californian experience of water banks, it can be described as generally positive, in that this type of market has helped minimize the economic and environmental impacts of droughts. Nevertheless, some authors [39,40] have also highlighted negative aspects, such as greater overexploitation of groundwater and a decline in economic activity in water-origin areas. These negative effects have become a matter of current social concern that has led to water banks being ruled out as a way of managing the more recent droughts.

3.2. Water Banks in Other Western US States

In the Western US states there are a wide variety of regions that, like California, are semi-arid and prone to highly variable rainfall and water regimes. This climate variability causes droughts and, in an effort to reduce the consequent adverse effects, many of these states have implemented water banks, among other measures. Below is a brief summary of relevant examples of water banks developed in these states.

Idaho was one of the first states to begin to set up water banks. This state has a long tradition of implementing water banking activities, allowing agents to not only store unused water in pools (sets of water rights "deposited" and physically stored for water banking activities) for future use, but also to sell stored water to third parties. However, it was not until 1995 that the state government formally developed a water bank that enacted active strategies to acquire, for environmental purposes, temporary and permanent water rights from the pools of the Upper Snake, Payette, and Boise River Basins. Subsequently, in 2001, the Lemhi River Basin water bank was created with the same purpose [41]. The objective of these water banks is to correct environmental damage caused by the federal government's large hydroelectric dams in the Columbia basin (with a special focus on salmon recovery), for which they receive funds from the federal agency, Bonneville Power Administration (BPA) [35].

Montana is in the Columbia River Basin, and so this state also benefits from the funds channelled through the BPA. However, in this state, those funds are managed by an environmental NGO. The NGO uses the funds to buy rights through a water bank which, in this case, is referred to as a water trust. The Montana Water Trust, in operation since 2001, aims to restore the water flows in the Columbia River Basin.

A water bank was created in Colorado in 2001 to encourage the reallocation of resources among users of the Arkansas River Basin. This state-run bank initiative was designed to implement a passive strategy via an online platform, with its operations limited to facilitating contact between buyers and sellers, and intervening as a clearinghouse for the operations, which were closed electronically. However, this attempt to institutionalize a water bank failed and not a single transaction was completed. A fundamental design error was the publication of the details of users interested in making a transaction, which allowed sellers and buyers to contact each other directly without the intermediation of the bank, thus reducing the transaction costs of operations. Following this unsatisfactory experience, the state of Colorado created another water bank in 2009, which this time was successful: the Colorado West Slope Bank. It is an active bank that was established for the reallocation of resources from long-standing rights holders (seniors), to more recent users (juniors). Lastly, attention should be drawn to the Colorado Water Trust, whose aim is to purchase temporary water rights for environmental protection purposes.

In the case of New Mexico, different types of water banks have been set up: both state-run and private initiatives, and implementing either active or passive strategies. The state water banks were created to acquire rights, both temporary and permanent, as a way of preserving the flow of the Pecos River. All of them, however, registered limited or no activity, with the exception of the Pecos River Water Lease/Purchase Program, which generated moderate levels of activity to fulfil the requirements of water flows around the Texas state line. Private banks, on the other hand, are oriented exclusively towards resource reallocation, having been developed by their organizers as for-profit entities [42].

Another state where a water bank has been set up is Texas, with the creation of the Texas Water Bank in 1993 as a mechanism to allow voluntary transfers of water rights between sellers and buyers, either temporarily or permanently. The bank acts as a clearinghouse of sales transactions and keeps a record of the activity carried out. However, the activity of the Texas Water Bank has been very limited due to poor institutional design, resulting in high institutional transaction costs, limited public awareness, inadequate rules for groundwater operations, and issues with water rights cancellation statutes, among other problems. Indeed, one particular obstacle was the prior existence of efficient brokers that competed with the bank by operating with lower transaction costs [35]. In addition, the Texas Water Trust was established in 1997 and is responsible for sourcing donations from individuals, companies, and institutions for the lease or permanent purchase of water rights for environmental purposes.

There have been water banks in Oregon since 1993, the year in which the Oregon Water Trust was established, becoming the first organisation of its kind in the world. It is an environmental protection organization also dedicated to restoring the flows of the state's rivers.

As a final example from the US, the case of Washington State should be mentioned. The not-for-profit Washington Water Trust has, since 1998, been responsible for restoring natural flows of water in the Yakima and Dungeness Rivers. It does so by means of public offers to buy temporary rights (in drought years) and permanent water rights [43], in addition to contracts for long-term options. In the same state, the Dungeness Water Exchange has been in operation since 2013, created by the Washington State Department of Ecology to run two demand-management programmes. The first, called the 'mitigation programme', consists of the establishment of a water bank so that new domestic users have access to water. In the absence of greater water availability, these users must purchase a certificate that guarantees that they will fulfil any of the water conservation options established for this purpose. The money raised by the certificates will go to purchase water from willing sellers. However, it is worth commenting that this certificate has proved to be something of an obstacle because water users cannot fully participate in the market until the water rights certification process is completed, and this process can take a long time to complete. The second programme, called the 'restoration programme', uses state, federal, and private money to purchase water in order to restore the river's flow.

3.3. Water Banks in Australia

Australia has the most active water market in the world. This market has been in operation since it was first approved in the 1980s, initially only for temporary rights transactions, but as of the 1990s permanent rights have also been traded. In fact, it is estimated that approximately 20% of the water used in this country comes from commercial transactions. In this context, it is worth mentioning that a great deal of the water transactions in Australia are carried out with the support of intermediaries, including brokers and lawyers. These intermediaries have gained the confidence of water users—predominantly irrigators—and some have subsequently gone on to create and manage water banks operating as clearinghouses that are intensively used for water trading. In fact, as Bjornlund and McKay [44] point out, local brokers are preferred for arranging transfers locally, but water banks are favoured for long-distance transfers. The aim of these private water banks is to promote resource reallocation driven by market forces, adapting supply and demand in both the short (temporary rights transfers) and long term (permanent rights transfers). Exchanges of water in these banks are performed via two passive-strategy mechanisms: (i) through the internet, by means of a bulletin board where buyers and sellers publicize their offerings, allowing operations to be matched up in terms of price and volume; and (ii) through sealed bid double auctions, as they are in stock markets [31]. The volume of operations and adaptation of market prices to changing conditions suggest that these water banks have been successful as a reallocation instrument for available water resources.

From 2004, as a result of the severe impact of the so-called "Millennium drought" on the status of its water bodies, successive programmes have been proposed in Australia for purchasing permanent rights for environmental purposes (mainly through the "Living Murray Initiative" and "Restoring the Balance" programmes). These programmes have acted as public water banks and make public offers to purchase rights (active strategy) charged to the public budget [18].

3.4. Water Banks in Spain

Water markets and water banks were introduced in Spain in 1999, when the law in force at that time was amended. The reform set out the regulations for the creation and operation of water exchange centres. According to Spanish law, water banks in Spain can only be publicly-run and require authorization by the Cabinet. In addition, these exchange centres, which adopt an active strategy, act only in "exceptional situations of water scarcity" (special drought situations or severe overexploitation of aquifers). Once set up, these centres operate through Public Offers of Acquisition of Rights (OPAD, in Spanish), whether temporary or permanent, in order to reallocate water among users in need of the resource or to improve the status of water bodies.

There has been a relatively low level of activity in the Spanish water markets, and it has only occurred in periods of drought. In fact, in the market's busiest year (2007) the volume of water exchanged amounted to less than 0.5% of the total water used at the national level [45]. In any case, most water exchanges have been performed through lease contracts; only a quarter of the operations have been conducted through water banks.

To date, three banks have been created in Spain that have acted in exceptional water situations. These exchange centres are in the southeastern part of the country, which is the driest area with a similar climate to the regions discussed above. Below is a brief summary of these water banks.

The first Spanish water bank was set up in the Guadiana River Basin, in response to the overexploitation of the Mancha Occidental aquifer; the existing water rights concessions represent more than twice the amount of the available resource. Between 2006 and 2008, six offers for permanent purchase were made as a way to restore the water balance of the aquifer. The prices paid related to units of irrigated area (on completion of the purchase sellers would have to stop irrigation) rather than units of water volume. Prices varied depending on the type of crop (annual or perennial) and proximity to the most deteriorated area. If we translate those prices into volumes of water associated with the surface for which water rights were acquired, prices ranged between €2.28 and €2.35/m^3, with a total cost of just over €65 million. There is no firm consensus as to the volume of water the bank was able to buy back, because, in some cases, water that had not been used in recent years was bought (sleeper rights), and also some of the acquired rights were allocated as grants for social crops, such as grapevines [46]. The activity of this water bank, which was expected to continue over time, was halted as a result of the economic and budgetary crisis that Spain has been suffering since 2009, which forced cuts to public spending on environmental policies such as these.

The second water bank experience occurred during the drought of 2005 to 2008 in the Júcar River Basin, where temporary water rights were purchased to maintain water flows in the middle stretch of the Júcar River, between 2006 and 2008. For the four offers made, a fixed price was set based on the apparent productivity of the crops in the area. As a result, the initiative resulted in the acquisition of a total water volume of 77.9 Mm^3 at an average price of €0.19/m^3 in 2006 and €0.25/m^3 in 2007 and 2008. The experience was considered fairly successful because substantial improvement was reported in the flow in the middle stretch of the Júcar River [47].

During the same drought, a water bank was established in the Segura River Basin and was in operation between 2007 and 2008. This water bank also made offers to purchase temporary water rights, with the aim of restoring environmental flows in the Mundo and Segura Rivers and ensuring water supply to local populations. These offers were successful in buying back about 6 Mm^3 at an average price of €0.17/m^3, which was eventually allocated entirely to the improvement of the environmental flows of the rivers [48].

3.5. Water Banks in Chile

The water market in Chile is known for its free-market doctrine [49], with fully decentralized and deregulated operations. This institutional design for the development of water markets has allowed the establishment of an active market for water rights among users, which has enabled both cyclical and structural shortages to be tackled. However, a number of criticisms have been levelled at its performance: imperfect market structure (oligopolies), lack of information on the operations carried out and poorly-defined water use rights [50]. These factors have caused high volatility in prices. Despite the great concern that exists in this country on how to improve the management of these markets, to date there has been no institutional reform in this regard. In any case, it is worth outlining the results of the pilot project developed in the Limarí River as part of the "Electronic Market for Water Rights" (MEDA, in Spanish) initiative. This initiative consisted of implementing a broker-style online trading platform with the aim of promoting transactions between potential buyers and sellers. This pilot project was in operation for several years, but ceased operations due to lack of public funding (MEDA ended in April 2011).

4. Water Banks as an Instrument for Managing Water Scarcity

Despite the potential displayed by water markets and water banks as instruments for efficient management of water scarcity (both structural and cyclical), a study of the experiences of water banks around the world reveals how their operation entails a number of advantages and disadvantages, which should be taken into account to ensure the appropriate design and implementation of these economic instruments. In this regard, an extensive review of the existing literature on the subject has been carried out in order to properly catalogue the main advantages and disadvantages associated with water banks, as summarized below.

4.1. Advantages of Water Banks

Since water banks are a type of water market, they offer the same advantages, mainly related to improved efficiency in the use of water [17,36,51–53]:

- They increase utility (income in the case of private, profit-maximizing agents) for all market agents (buyers and sellers of water). The participation of water users in the market is always voluntary, which ensures that all operations are beneficial (raised utility or income) to both parties.
- They improve resource-allocation efficiency, encouraging water transfers from activities of lower value of marginal utility (value of marginal productivity in the case of productive economic uses) towards activities with higher value of marginal utility, thereby maximizing the total utility (production value in the case of productive economic uses) generated by all agents participating in the market. As a result, in those cases where externalities are minimized, water banks usually lead to improved social welfare (net benefits from a public perspective).
- Market prices provide a proxy of the true opportunity cost of water, encouraging more rational use of the resource.
- They can ensure better supply security to the users that are most averse to the risk of hydrological uncertainty, since they provide the possibility of water exchange in times of water shortage.
- They rationalize the construction of new infrastructure projects aimed at increasing water supply, as the markets provide an alternative to building expensive water works (when market prices are lower than the marginal cost of new resources).

In addition to the advantages they share with other water markets, water banks offer a number of specific advantages [35,42,54–57]:

- Water banks centralize purchases and sales of water rights (or options), reducing operational or static transaction costs for both the agents involved in the market and the institution managing the bank. Transaction costs are a key issue in environmental policy [58], and are also a key factor determining the performance of water institutions (e.g., water banks) [59]. For a recent review of transaction costs in environmental policy, interested readers can consult [60,61]. With a more specific focus on water markets, Bjornlund et al. [54,62] are also worth referring to. Following recent debate, transaction costs can be divided into two categories: the first refers to the costs of designing and setting up the instrument under analysis (namely *institutional transaction costs*), while the second are associated with the operational costs of the instrument (namely *static transaction costs*). These static costs include: (i) support and administration costs; (ii) contracting costs; (iii) monitoring and detection costs; and (iv) prosecution and enforcement costs. Water banks are particularly effective at reducing contracting costs. This advantage is the most important one for market agents, since it involves the costs of finding parties interested in participating, bargaining costs, and decision costs associated with transactions. The reduction of all these static transaction costs boosts water trade by making operations more profitable (or ensuring they generate more utility in the case of public or non-profit organizations) for buyers and sellers.

- Water banks encourage governmental oversight of environmental and social externalities arising from water transactions. 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.
- They make the market more transparent by releasing purchase/sale prices and making them publicly available to all users.
- Public initiative water banks, since they are managed by the government, provide greater security and reassure buyers as to the actual availability of negotiated water resources.
- The implementation of water banks during the early stages of drought periods should more effectively raise all users' awareness of the need for efforts to reduce demand in order to mitigate the negative effects of drought.

4.2. Disadvantages of Water Banks

There are a number of disadvantages associated with water markets, and which are, therefore, also associated with water banks. Below is a list of the main drawbacks inherent in the use of these economic instruments [9,10,47,55,63,64]:

- They could generate negative environmental externalities, especially by altering water flows in natural watercourses. This occurs firstly through changes in the location of uses, which can reduce flows (sale of water from the lower to the upper part of the basin) or increase flows (sales in the opposite direction). Secondly, it occurs through the overall decline in returns when transfers are made from areas of low-efficiency water use to areas of higher-efficiency water use, resulting in an increase in water depletion (reduction of natural flows) at the basin level.
- They could generate social externalities in the areas of origin, due to the loss of employment caused by abandoning productive activity, which can in turn cause depopulation and territorial imbalances. Such issues could then present a political problem (e.g., rural stakeholders in areas of origin lobbying to maintain irrigated agriculture).
- The activation of "sleeper rights" or "paper rights". The presence of the market encourages the activation of these rights, resulting in an increase in the water abstraction from the system, a situation that exacerbates water shortages.
- Existence of other market imperfections, resulting from the small number of buyers and/or sellers, the variety of water rights exchanged and/or the lack of transparency in the information on volumes transferred and prices negotiated. A further consequence of all this is that the balance achieved by the markets is sub-optimal from an economic efficiency perspective. In this regard, it is worth noting the impact on the market of cultural barriers (unwillingness to use water markets as water is not considered a tradable commodity), physical barriers (lack of appropriate

infrastructure for completing transactions) and legal barriers, which limit the number of agents that can operate in it.

It should be noted that water banks, as well as sharing the same characteristics as water markets, also have some specific features which result in a number of unique disadvantages not displayed by other water markets. In this regard, it is worth highlighting the complexity of the institutional design required for the creation and operation of water banks, especially in contexts where there is little prior experience with water markets [65]. Consequently, water banks have greater institutional transaction costs, understood as the costs of designing and setting up this instrument incurred by the institution responsible for its creation [61]. This is because the establishment of a water bank requires high levels of investment and administrative management capacity. In addition, if it is an active water bank, it requires a large budget to carry out acquisitions and to be able to withstand the risk associated with such operations (possibility of losses). For these reasons, the organization and implementation of this instrument is generally only feasible for public administrations.

To summarize, we believe that the advantages of water banks outweigh the disadvantages, many of which can be limited through appropriate institutional design of the instrument. As a result, this type of market is becoming ever more common around the world as an economic instrument for improving efficiency of water use and mitigating the effects of water shortages (cyclical or structural) [17,66].

4.3. Critical Features: Defining Successful Water Banks

The decision-makers responsible for water policy face the challenge of designing economic instruments for the improvement of water management [67]. Accordingly, analysing related international experiences can be extremely informative, revealing the key factors behind the success or failure of such initiatives. In the analysis of water bank experiences, three key elements should be taken into account as determinants of performance: (i) the water economy context; (ii) the institutional context, and (iii) the social context.

In terms of the *water economy context*, the development of successful water banks (or any other market-based instrument) requires a "mature water economy" [3], that is, an economy with a high, but still growing, demand for water combined with an inelastic water supply in the long run due to the limited possibilities of securing new water resources. Within this framework, policy reforms should involve two linked components: cap (imposition of diversion/extraction limits to avoid further sustainability problems) and trade (establishing tradable water rights to enable more flexible water reallocation) [54]. Thus, the use of markets mechanisms has been encouraged to be (cautiously) implemented in mature water economies [68,69]. In this sense, water banks can be useful in two different ways. First, by directing permanent transfers of water rights towards higher-value uses, and second, by allowing temporary water transfers in order to manage periods of water scarcity (droughts). Considering the widespread and long-run impacts of permanent water transfers, some doubts arise as to the suitability of instruments that rely purely on private incentives (market-based instruments such as water banks) to reallocate permanent water rights. On the contrary, permanent transfers dictated by the public interest (i.e., public acquisitions aimed at improving social welfare) can be justified both in terms of reallocation between economic users and for environmental purposes.

In any case, temporary water banks have been proven to be a useful instrument for managing cyclical water shortages (droughts), providing a flexible and cost-effective tool for reallocating water from lower-value and more drought-resilient uses (e.g., irrigation farmers with herbaceous crops) to higher-value uses, both for private operators (e.g., urban water suppliers) and for environmental purposes (e.g., maintenance of water flows by public authorities or environmental NGOs).

Within the *institutional context*, it should first be noted that water rights must be clearly defined before implementing water banks. In fact, the creation of a centralized register of water entitlements exactly defining water allocations, use permits, etc., it is a strictly necessary condition for an adequate performance of any market mechanisms [70,71]. Particular important is water use priority, which can vary greatly among users and sectors and especially where prior appropriation rules exist, meaning that water users in the same basin can have different water rights. This makes it difficult for these heterogeneous rights to be traded thought permanent water banks. In this regard, an interesting feature of temporary water banks is that they do not require homogeneity of water rights, since only water volumes (not rights) are traded; this, along with the doubts about permanent transfers driven by private incentives, means that temporary water banks are more likely to succeed than permanent ones. In fact, successful experiences of permanent water banks can only be found in cases where they have been managed by a public authority (public control of long-run externalities) and/or for environmental purposes (a public administration or NGO purchasing rights to reduce water depletion at basin level).

Moreover, it should be noted that temporary water banks for the reallocation of water rights as a production input have had notable success in basins where spot water markets had already been implemented. This evidence suggests that spot water markets can be considered as a first stage in the implementation of market-based instruments in mature water economies. Once the private agents involved have confirmed the potential profitability of making water transfers via this decentralized instrument, market activity can be expanded (and economic efficiency improved) in a second stage by the implementation of temporary water banks. The success of this approach to the design of water banks is supported by two key characteristics of the process. First, the prior implementation of spot water markets generates the required "market training" for private operators, showing the economic value of water resources (market prices) and demonstrating how water transfers can be profitable for both buyers and sellers. Second, the activity of these market-based instruments usually occurs in a thin market at first (water users are reluctant to sell water for cultural reasons) and so, at this initial stage, it is only worth implementing simple institutional arrangements, such as spot water markets. Only when market operations reach a critical mass are the investments needed to create a water bank (institutional transaction costs) justified, regardless of whether it is a public or a private initiative. With large enough markets, water banks become a more suitable instrument than water markets since they reduce static transaction costs in relative terms, thus leading to more efficient market performance (more operations and more value creation).

In addition to the accurate definition of water rights and previous experience with spot water markets, an appropriate design for water banks is also a key determining factor in the success of this instrument. We can cite a few examples of poorly designed water banks in order to illustrate this point. For instance, the Arkansas River Basin Water Bank Pilot Program failed mainly because it was designed as a passive water bank that published detailed information about all willing buyers and sellers. This made it possible for interested agents to arrange sales agreements outside the bank by contacting each other directly, thus avoiding the bank fees. Another clear example of failed design is the Texas Water Bank, which has registered minimal activity since 1993. This is, among other reasons, because it was designed as a complex operational institution (high institutional and static transaction costs) simply acting as a clearinghouse in a region with a long tradition of spot water markets with efficient private brokers that, thanks to their lower costs, were able to successfully compete with the bank for market operations. Lastly, it is also worth highlighting the case of the Guadiana River Basin Exchange Centre (Spain), an active water bank created for environmental purposes, which partially failed in its objective because the public offers to acquire rights had the effect of activating rights that had not actually been used in recent years (sleeper rights). In this case (and with other similar banks implemented in Australia), the failure to correctly define which rights were eligible for purchase in the public offers resulted in large public expenditure without any environmental improvement (real reduction in water abstractions).

Finally, regarding the *social context*, it should be pointed out that water banks have undergone remarkable development in areas where environmental problems (e.g., extractions over sustainable limits) are a source of social concern. In an attempt to minimize these problems, water banks have proven to be a useful tool for balancing water extractions, by leasing (temporary) and purchasing (permanently) water rights without subsequent reallocation. In these cases, water banks have allowed public administrations and environmental NGOs (e.g., water trusts) to participate in the market in order to reallocate water for environmental purposes, with these operations being covered either by the public budget (the society as a whole) or by voluntary private support (voluntary contributions from individuals and private institutions), respectively.

Furthermore, in order to ensure a successful implementation of water banks for resource allocation, any social concerns about negative externalities (environmental or social) should also be taken into account. The Californian experience is quite instructive in this regard: despite the successful experience in 1991 of using water banks as an instrument to manage droughts, this instrument failed when implemented in 2009. One of the reasons behind this failure was the opposition from particular sectors of Californian civil society which noted that water transfers would not be beneficial to society as a whole due to negative environmental and social effects. This case illustrates that, in order to achieve a successful development and operation of water banks, it is not only the current water users that must be taken into account, but also other stakeholders, in order to ensure, as far as possible, that water exchanges are perceived as beneficial for the whole society.

5. Conclusions

The analysis conducted reveals that water banks in the Western United States and Australia are active and well-established. In other countries, such as Spain, where such water markets have been in place for less than a decade, operations are gradually becoming more established [45]. The analysis of these international experiences with water banks has demonstrated that water banks are a market mechanism that facilitates transfers of water towards uses of greater value, including environmental uses. Thus, it can be said that this economic instrument is a useful tool for minimizing the negative impacts of water scarcity, whether cyclical or permanent. Indeed, the introduction of this type of water market makes the allocation of water use more efficient and also provides a tool to (partially) solve environmental problems linked to the overexploitation of water bodies. Moreover, compared with other types of water markets, water banks reduce the static transaction costs associated with support and administration, contracting, monitoring and detection, and prosecution and enforcement, thus helping to create more active water markets (increased economic efficiency). They also centralize market operations, which allows the administration (or other agency) to properly control potential negative externalities and prevent any kind of harmful speculation.

Nonetheless, the review carried out has also exposed some shortcomings in the implementation of water banks around the world. In this regard, a number of suggestions for improvement that the authors believe would help minimize or overcome these drawbacks are presented.

- As with any water market, water banks can generate two main kinds of environmental externalities. The first is the change in water flow regimes, which could be harmful for aquatic ecosystems. In order to address this potential externality, operational rules of water banks need to include criteria for approving transfers, which guarantee that they are compatible with maintaining minimum environmental flows in all natural water courses affected. The other environmental externality is the likely increase in overall water consumption at the basin level because more efficient irrigation practices lead to less water flowing back to water bodies [72]. In order to reduce this negative environmental externality, operating rules of water banks must ensure that the total water rights transferred tally with the volume of water actually consumed (water extracted from the source that does not return to water bodies) in previous years. This is the only way of verifying that water bank operations do not increase water depletion, which would increase the quantitative pressure on water bodies and reduce water flows in natural watercourses. In this regard, a two-step approach is proposed. First, appropriate mechanisms are required to prevent the transfer of water rights that are not being used (sleeper rights), a situation that leads to an increase in total abstractions. Second, rules must be put in place to limit the amount of water transferred to the amount actually 'consumed' by the rights-holders (only the water evapotranspired by crops, in the case of irrigators), rather than the amount 'used' (total water abstracted from the source). In other words, water banks should avoid transferring the fraction of water corresponding to return flows. This is the only way to make sure that the water bodies in the areas of origin maintain the levels of water extraction that predate the banks' operations [15]. To that end, both the volume of water effectively used in previous years and the technical efficiency in water use would have to be determined in order to calculate the volume of return flows. Consequently, the volume of transferable water should be limited to the water abstracted from the water bodies minus the returns that would have originally occurred.

- Transaction costs are also a relevant issue when designing and implementing water banks. As McCann [73] shows, a monopsony structure, as the one provided by water banks, may facilitate bargaining, easing contact between users and a central operator instead of between users, thus reducing static transaction costs. In any case, an efficient initial design of these banks is required in order to minimize institutional transaction costs. Before creating this kind of centralized market, bank developers should be encouraged to examine the current water market framework: agents, 'market training' (experience in water markets), number of agents previously operating in the market and volume of water or rights traded, the role of private brokers, etc. This analysis should help inform decisions regarding the timing (when to create the water bank) and structure (market infrastructures and the design of operational rules) of the bank to be created. It is also worth mentioning that static transaction costs should also be minimized by setting up appropriate operating protocols and boosting the use of information and communication technologies (integrating operations applications with public water records databases), geographic information systems (GIS), and remote sensing techniques. This would allow the following procedures to be streamlined: (i) the presentation of offers/demands by stakeholders; (ii) verification of the information they provide (e.g., water rights held, location of abstraction, consumption and effective use of the rights in recent years); (iii) approval of operations and the execution of the corresponding financial transfers; and (iv) compliance (e.g., ensuring that users who transfer their rights do not subsequently use them).
- Well-designed water banks, as well as any other water policy, must improve transparency by making all market information available to the public [71]. Such information includes the parties involved, prices and trading volumes agreed, terms of the offer, etc. This information should be made public in real-time through the websites of the basin authorities. In addition, the managing organizations of these banks should publish an annual report of activities which details the effective contribution they make to water governance as, in fact, some of them already do.
- All water banks should be self-financing as promoted by some water legislations, such as the EU's Water Framework Directive [74], where the principle of full cost recovery is a key issue. This means that the prices paid by buyers must cover not only the compensation required by the seller, but all operational and management costs relating to transactions, including water conveyance costs if transportation is needed. In this way, even public initiative water banks can avoid any possible hidden subsidies to water users (e.g., irrigators).

Logically, legislative reform in the regulation of water banks would be needed in order to implement the proposed improvements. In this regard, it is recommended that such reforms are carried out during a normal hydrological period as a way to plan ahead (with the necessary time, analysis, and debates) for future shortages.

Lastly, it worth commenting that available (published) information about the performance of different water banks varies widely and is mainly qualitative. This has made it difficult to further analyse the existing case studies and make more consistent comparisons. We, thus, recommend that an international institution actually involved in water policy issues, such as the United Nations Environment Programme (UNEP) or The World Bank, launch an initiative to build and periodically update a database covering the main qualitative and quantitative features of water demand-side instruments (including water banks) implemented in each associated country. Through such an initiative, it could be feasible to ask different countries for official data on a voluntary basis.

There is no doubt that it would make a positive contribution to the objectives of these international institutions, since the availability of this official information could support sounder water policy decision-making worldwide.

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