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Inside stories of a successful water market

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Summary

The combination of increasing water demand, and more severe and frequent droughts, has reduced water security and increased water inequity throughout the world. In regions that have already allocated their conjunctive water supply, this combination of increasing demand and decreasing reliability in supply has created a policy conundrum of how to maximise the social benefits from water. Water markets provide one approach to reallocate water to those individuals who are willing to pay the most to access that water. However, while markets provide a mechanism to promote increased economic return from water use, questions remain concerning if market structures provide the capacity to include all parts of society. The adoption of water markets and water trading has occurred in some parts of the world, and each country has implemented different market rules, trading agreements, institutional structures, and participant access, with mixed levels of success. This chapter reviews some successful experiences of water trading in Australia, western US and Spain, describing how markets have helped in alleviating water related risks reducing the associated impacts. Despite these successful experiences, the potential of water trading is still underdeveloped in most cases due to several factors and barriers to trade. Some insights in relation to how to increase the success of a market for water are provided at the end of the chapter.

1. What is the role of water markets?

Globally, many freshwater ecosystems are suffering from significant overexploitation [1]–[3]. As water resources are essential for the preservation of life, livelihoods, and ecosystems, this combination of overexploitation, continuing increasing demands for water, and uncertainty associated with future water supply has allowed conflict over a shared resource to emerge. Conflict will continue as a combination of: inequitable income and population growth; urbanisation; changes in consumption habits; and the uncertainty impacts of a changing climate, will exacerbate problems related to future water availability [4]. Water insecurity and inequality then poses substantive threats to all countries' economy, social and the environment resilience.

Water scarcity is not unique to arid and drought-prone areas, but it is also evident in more humid and temperate regions where traditionally rainfall has been abundant. Water management often occurs by institutions and their regulations, but in many cases, they have failed to keep pace with the changing nature of water demand and supply. Governments are re-evaluating their strategies for dealing with water insecurity and water inequality for this and future generations. If new water strategies can deal with risk and uncertainty, then these resilient solutions provide a level of certainty for all water users. In some basins all available water resources have been already allocated to different users (irrigators, urban suppliers, industries, environment), and is not possible to fulfil more demands. When institutions prevent the access to more water, a basin is considered closed [5]. In closed basins, when water demand increases, the only way to meet this new demand (apart from water use efficiency gains) is through the reallocation of the existing water resources among competing needs. Even in basins that have not achieved the closure point, reallocation of water resources —either temporal or permanent— might be useful to use water for more essential needs and to avoid expensive supply investments or environmental crisis during shortages.

With the expected effects of climate change on water supplies and demands, some authors have pointed out to water markets as a cost-efficient adaptation mechanism [6].

A water market is “an institutional framework which allows water right holders, under certain established rules, to transfer their water rights to other economic agents or water users, receiving an economic compensation in exchange” [7]. As Getches [8] pointed out “the great virtue of creating property rights in water is that it can be bought and sold”. Water markets institutionalize water trading, allowing for a more efficient use of available water resources, reallocating water from low to high value uses, provided the right regulatory framework. The prices negotiated for these transfers provide useful information to all parties about the economic value of water, creating incentives for its conservation, to invest in local infrastructure to reduce conveyance losses from evaporation and leakage, and to coordinate infrastructure needs [9]. Whereas short-term transfers—sometimes called leases—are used for coping with droughts, permanent transfers are a demand-management tool to reallocate water. In Australia, California and Spain, transfers have been used to buyback water for the environment, to offset the risk of drought to capital, to increase reliability of urban water supply, to reallocate water from low- to higher-value crops [10]–[13]. In most of the cases, a majority of sellers are farmers with higher reliability in their property rights and lower economic benefit in their water use application, whereas buyers are much more diverse.

2. Why, when and where a market for water has been established?

Establishing water markets is one approach for improving water economic efficiency. However, very few countries have established formal water markets. Besides, in countries where water markets are regulated and authorized, exchanges are not quantitatively that important. Water markets exist in different parts of the world, mainly in those areas with water scarcity problems or with an irregular distribution of water resources among seasons, users or regions. Australia, Chile and some parts of the USA, including California, are home to long-active water markets, yet they have very different structures, designs, institutional settings and different degrees of market intervention [14]. For example, in Chile and Australia, the management of these markets is more decentralized. Australian water markets are probably the most developed in the world, and in some basins, exchanges can be ordered, managed and monitored electronically. Despite these differences in market design and implementation, similarities related to the: problems in the definition and registration of water rights and their supply reliability; predominant role of agriculture as the main water seller, the prevalence of temporary exchanges of water; prices dispersion; and increasing concern for the environmental impacts, exist in these countries. Many of these resemblances can also be found in other regions like Spain, Mexico, Canada or South Africa, where water markets have also been created but their use has been very limited to date [12], [15].

In many arid and semi-arid developing countries, with limited social and institutional capacities, the adoption of markets for permanent water rights has been hesitant; while informal markets for temporary transfers have been more widely adopted, since no change of ownership takes place [16]. Such is the case of China, India and Pakistan, where informal groundwater markets between farmers, characterized by the lack of official government administration, have spontaneously emerged [17], [18].

While there is not such a definitive set of requirements that need to be in place for water markets to occur and success, an analysis of the experiences and academic writing reveals certain preconditions that point to the effective operation of water markets. These include, among others:

- The existence of resource scarcity along with differences in water productivity between potential buyers and sellers, as well as sufficient willing market participants [19].

- The establishment of an effective cap on total sustainable extractions and then allocated among users [20].

- Well defined property rights in a manner that they are completely specified, monitored, enforceable, transferable and legally secured [21].

- Unbundled water rights (access, use and delivery components) separated from land rights [22].

- The presence of physical infrastructure so that the purchased water can be transported, at a reasonable cost, to the new owner [23].

- A sound regulatory and governance framework within which water trading can take place including the existence of enforcement and sanctioning mechanisms [24].

- The availability of information on water concessions and water market prices and volumes traded in a fashion manner so that transaction costs may be reduced [12].

The degree to which each of these preconditions is achieved in the alternative water markets is, of course, a continuous variable. Nonetheless, it seems that the fulfillment of these preconditions has been instrumental in explaining the different degree of success -or failure- of different countries in using water markets [25]. For example, in Australia's closed basins, property right design and desire to use markets for water reform have resulted in clear market rules, regulations and transparency to make the market as functional as possible. All these changes, together with the political will and the willingness to allocate real resources towards solving the over allocation problems has allowed its water markets to develop.

Transition towards water markets has usually taken place gradually as water demand increases and fresh water becomes scarcer. Yet, there have been other circumstances which have prompted the adoption of this economic instrument as a tool to reallocate water, such as the occurrence of extreme events (e.g. droughts), changes in environmental regulation, or because of economic feasibility [26]. In Australia, the first tentative steps towards water trading took place in the 1980s, although water marketing did not gain traction until the Millennium Drought (1997-2010) changed preconceptions and expectations about known water supply in the Murray-Darling Basin (MDB), Australia's food basin. By 2006, the drought provided the political impetus to force regulatory changes and to develop the 2007 Water Act. The Water Act amongst other issues, proposed both the development of a MDB Plan (the Plan) to establish environmental rights and to establish institutions to identify and negate barriers to water trade [27]. This legislation allowed the rapid growth in water market volumes, transfers and allowed irrigators to learn about the real price of water.

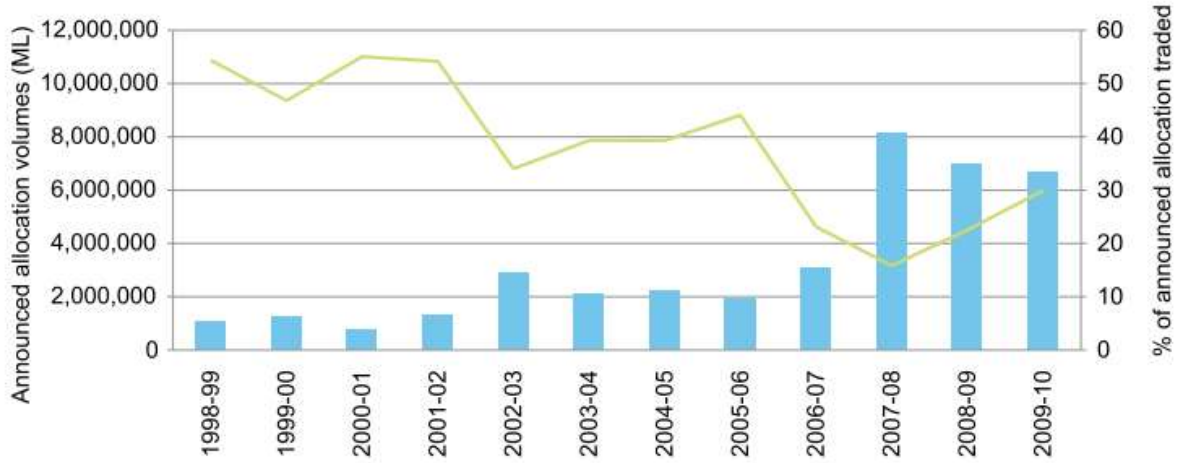

Figure 1 Water Allocation sales (blue bars) as a percentage of water allocated (green line) in the Southern MDB 1989-99 to 2009-10. Source [28].

The MDB is home to one of the most mature water markets in the world, accounting for over 80% of all entitlement trade and seasonal allocation trade in Australia, representing around 30% of water allocated in a given water year [28]. Overall, the MDB has proven to be a mechanism to: provide private wealth by engaging in trade (local, regional and inter-state); provide a facility to help mitigate drought risk, and provide a solution to offset negative outcomes from the use of water, but the market and its rules will continue to evolve.

Although to a different extent and with different outcomes, the transition towards water markets in California has followed a similar pattern of gradual development triggered by the occurrence of droughts and the increasing environmental concern [29]. Water markets were first envisioned in California in the late seventies when the combination of scarcity, urban expansion and intensive agricultural production raised awareness on the necessity of adopting measures to guarantee water supply and agricultural production. In this context of water scarcity and changing water demands water markets were primarily encouraged as a mean to enhance water efficiency. However, it was not until the late 1980s and early 1990s when a seven years drought accompanied by several water reforms took place, that water markets started to be broadly adopted. Apart from this significant drought episode and similar to Australia, environmental concerns and subsequent environmental water trading also played a major role in boosting water market activity in California during the years 1995-2002. During this period, environmental purchase increased three times faster than the market as a whole, mainly due to the rise in environmental water purchase through federal and state programs such as the USBR's new Water Acquisition Program and the CALFED's new Environmental Water Account [29]. These and other measures and legislative changes, have allowed water marketing in California to grow significantly over the past three decades. Today, water trades represent about 5 percent of all water used in the state. Trade has developed into an invaluable tool for helping California manage its scarce water resources more efficiently and sustainably over the long term, as well in its ability to cope with periodic droughts.

Transition towards water markets adoption in Spain provides a different picture. Law 46/1999 incorporated formal water markets into the Spanish legal and regulatory framework in 1999, allowing for spot water markets and water exchange centers to be developed. Though it has been fifteen years since water trading was allowed, limited improvement has taken place in the performance of water markets. Since their implementation, there have

been relatively few water transactions, most of them during the drought period (2005 to 2008) in a spot market and among agricultural users [12], [30].

In view of the above, Australia and California seem to illustrate a similar approach to water markets. In these regions water markets are not considered an exception, even if they represent a small share of the total amount of water used like in California [31]. The opposite is true in Spain where, as showed by evidence, water markets are regarded as exceptional rather than representing a major institutional change, use of water markets have mainly constituted a "disaster management strategy" [32]. A deeper insight into the specifics, outcomes, and examples of each of these case studies is provided in the next section.

It is worth stressing that although successful examples of water markets implementation and performance do exist, they are relatively scant. Most of the countries adopting water markets have made an effort in removing barriers to trade to enable the market to re-allocate water to its highest use value. However, water markets implementation is still hindered by social, economic, environmental, physical and cultural barriers that have proven difficult to overcome (see Section 4 of this chapter). It is also worth mentioning that despite in real world water markets generally deviate from an ideal textbook market, these do not preclude the possibility of a well-functioning and socially beneficial water market as case studies provided in the next section illustrate. As it happens in other natural resources markets, the potential performance of water markets will ultimately depend on their wider contexts and preconditions, i.e. legal rules, political choices, economic and geographic conditions as well as cultural practices [33].

3. Water trading experiences – A story of success?

Currently, water trading activity is helping to alleviate water scarcity problems in many regions worldwide [34]. This section presents some examples of successful water trading experiences in Australia, California and Spain, to highlight the benefits of implementing a market for water as a reallocation mechanism. Besides, the reasons that limited the water trading potential are discussed.

3.1. *Australia*

3.1.1. Water Markets in Australia (focusing on the Murray-Darling Basin)

To explore the development and evolution of water markets in Australia, this section builds on Alex Marshall's [35] key intertwined components of market design that include: allowing market rules and strategies to evolve over time; property rights; legal settings; corporations and intellectual property; physical environment; and the necessity for, by adding political will, transparency and environmental holder.

The Murray-Darling Basin is Australia's natural experiment in water reform and water markets. The MDB: covers and area greater than over 1million Km^2, has over 50% of all water used for irrigation in Australia; and has over 65% of Australia's irrigated land [36]. Water resources in the MDB are over allocated and the transition towards market-based solutions is a political recognition that the supply-based measures do not solve environmental problems [27]. Adding complexity to the markets is that the MDB has the 2^{nd} most variable inflow in the world [37] and water markets are considered as a key risk management tool to combat drought [38].

3.1.2. Legal settings, institutions and property rights

While books have been dedicated to explaining the legalities of water market development in Australia [39], this section has limited its discussion to the three major reforms that identified that:

- An upper limit (or cap) on water extractions had to be implemented and that water trading must have consistent rules between all states (1994 COAG Water Reform Framework, [40]).

- that for trade to work water entitlements must: specify the product, be legally recognised by all states and territories, be able to be traded or leased, and understand that the product is subject to climatic variability, and that the market needed clear rules to minimise transaction costs, and be free of current barriers to trade (2004 National Water Initiative, [41]); and

- the 2007 Water Act [42] that enacted: the National Water Commission to identify and help remove barriers to trade; allowed the Australian Competition and Consumer Commission (ACCC) to rule if there were unnecessary charges or fees that prevented individuals from engaging in trade; and provided detailed instructions on the development and implementation of market rules (see Section 4 of the Act).

The on-going development reflects the learning about how to set up markets and these legal settings were harmonised between all states to ensure that legal status of property rights. The 1994 'Cap' on water extractions essentially closed the MDB. While this closure was a step forward, it also highlighted that there was value in un and under developed property rights[1]. Consequently as rights were decoupled[2] from land, these rights were traded and subsequently utilised and exasperated environmental degradation [43]. Yes, property rights and trade can increase environmental harm.

To deal with the inherent variability of water supply, three classes of water rights exist within the MDB. These classes define the reliability of the property rights to provide water: high, general and supplementary water in a given catchment. Consequently, the bundle of rights within each catchment in the MDB is unique both in terms of the composition (i.e. number of rights by class), and the reliability of each right class. In other words, rights do meet the 2004 National Water Initiative guidelines, as the structure of these rights means that both buyers and sellers are aware of the 'marginal value' each right class by catchment has to their production system. This provides clarity to the market place to help price property rights.

3.1.3. Corporations and intellectual property

While the rules pertaining to trade and who can trade are defined by the government, private companies have been allowed to construct the clearinghouses to facilitate trade between private individuals. Consequently, trading platforms are deigned and operated by private companies to make a profit. Not only do they offer a place for individuals to engage in allocation or entitlement trade but they also offer information concerning the market, current water supply and links to forecasts and industry based information. The success of the private interaction in shaping the functionality of the market has allowed these platforms to be exported overseas, [44]

[1] These rights are often referred to as sleeper (undeveloped) and dozer (under developed) in the literature

[2] Decoupling is a process where rights are separated into separate bundles, this subsequently allows water rights to be sold or leased without needing to trade land.

3.1.4. Evolving Market Rules and Strategies

Market rules and strategies evolve over time as Marshall [45] wrote…

> "Again, markets vary with regard to the period of time which is allowed to the forces of demand and supply to bring themselves into equilibrium with one another, as well as with regard to the area over which they extend." (Book V, Chapter 1, Section6, page 192)

As individuals and private companies adapt and learn to manipulate market rules, legal frameworks, property rights, and the physical environment, over time, new rules and legal settings are introduced to fine tune the market and enforce rights. While the overall design of the markets attempts to minimise transaction costs, they are nevertheless evident.

Current market rules: define where and how water can be traded (surface, groundwater, and the trade between surface and groundwater) between catchments; if penalties (i.e. changes to volume) are applied to reflect the conveyance loss of water as it moves along the river (or between conjunctive sources); and provide the necessary legal frameworks to engage in permanent or allocation trade.

3.1.5. Market Transparency

Unawareness allows supernormal profits to be made in markets [46]. To prevent this, the development within Australian water markets, a combination of purchasing rights for the environment (i.e. the buyback) [27], and the public release of market information, has prevented information asymmetry. The Restore the Balance (or buyback) process in Australia helped irrigators discover the price of water in the MDB that the government was willing to pay [47] and in turn informed the private market of prices.

While reviews (monthly or annually) of water markets (volume traded, prices, where trade occurred) can be downloaded from government websites[3] and from private companies[4]. Such information then helps individuals plan new strategies for dealing with water markets.

3.1.6. Environmental Holder

The development of the Plan has created some uncertainty in water markets, as the government is now the single largest owner of water. The Plan follows the concepts of common-property [48] to deal with the over allocation of water in the MDB. The Environmental Holder will eventually manage between 2,750 to 3,200 GL of water for the environment and this will comprise of set of property rights that are identical to irrigators rights (i.e. as discussed the buyback was one economic instrument designed to transfer water from irrigators to the Environmental Holder[5]).

As the Environmental Holder: has to meet a range of environmental objectives; can trade water to reallocate its permanent portfolio; and engage in temporary trade to either buy or sell water to and from irrigators, the market will again face a series of new challenges and strategic responses. Inevitably, comments suggesting that the Environmental Holder will act in a predatory manor (buyer or seller) will have to be explored.

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[3] http://www.agriculture.gov.au/abares/research-topics/water/aust-water-markets-reports ; http://www.bom.gov.au/water/dashboards/#/water-markets/national/state/at

[4] http://www.aither.com.au/water-markets/water-markets-reports/

[5] Note the 2,750 to 3,200GL of water will come from the volume currently allocated to irrigators.

3.2. The US (California)

3.2.1. Introduction

The first major drought widely experienced by Californians occurred in 1976-77. It provided a wake-up call that exposed the inadequacy of past water supply planning and changed how policy makers thought about water [49]. The drought prompted major policy changes, and given the extensive supply plumbing already existent in California, demand management strategies were proposed as innovative solutions.

In a report to review California Water Rights Law [50] the Commission proposed "The Market Approach" to improve water use efficiency and identified the regulatory changes needed to encourage voluntary transfers of water rights. To achieve this the Commission proposed three critical tasks. One, ensure the security of the right, to incentivize water reclamation and avoid the risk of forfeiture under the "use it or lose it" doctrine. Two ensure the flexibility of the right to change the place of use, point of diversion and purpose of use and some other restrictions. Three, implement administrative reforms to speed up the permitting process.

Most of these recommendations were set forth in the water code in the following years, and the first actual water trades started in the early 1980s.

3.2.2. Water Market Stages

The coincidence of the beginning of the California water market with a wet cycle limited the initial amount of trading in the early 1980s. But another drought, between 1987 and 1992, spurred the market activity and cities, farms and the environment started to benefit from water transfers.

The establishment of the California Drought Water Bank in 1991 was a major institutional breakthrough, with the state approving and administering water trading [51]. The Department of Water Resources, in charge of operating the State Water Project that provides water supplies for 25 million Californians and 300,000 hectares of irrigated farmland, started purchasing water to offset lower deliveries to its contractors and wildlife refuges. Overall, during the period 1987-1994, state and federal agencies purchases for resale and environmental uses accounted for nearly half of the market activity [9].

The growth of the market continued during the second half of the 1990s, even though during these years California experienced on of the wettest cycles in the 20th century. If during the 1987-2012 drought most purchases went to Californian cities, during the second half of the 1990s San Joaquin Valley farmers dominated water purchases. Environmental deals grew largely also during this period, were the market kept growing even after the drought years.

The market achieved its maturity with the new century, and since then the amount of trading has been approximately flat. The composition of the trades has changed though. During the 20th century a majority of the trades were short-term leases (nearly 80%) and most of the remaining long-term leases. The 21st century has seen a stable growth of long-term leases and the appearance of a small but quasi-constant share of permanent sales (between 2001 and 2014 long-term leases accounted for 44%, long-term leases for 43% and permanent sales for 13%)[6].

[6] Own calculation using data from Hanak and Jezdimirovic (2016).

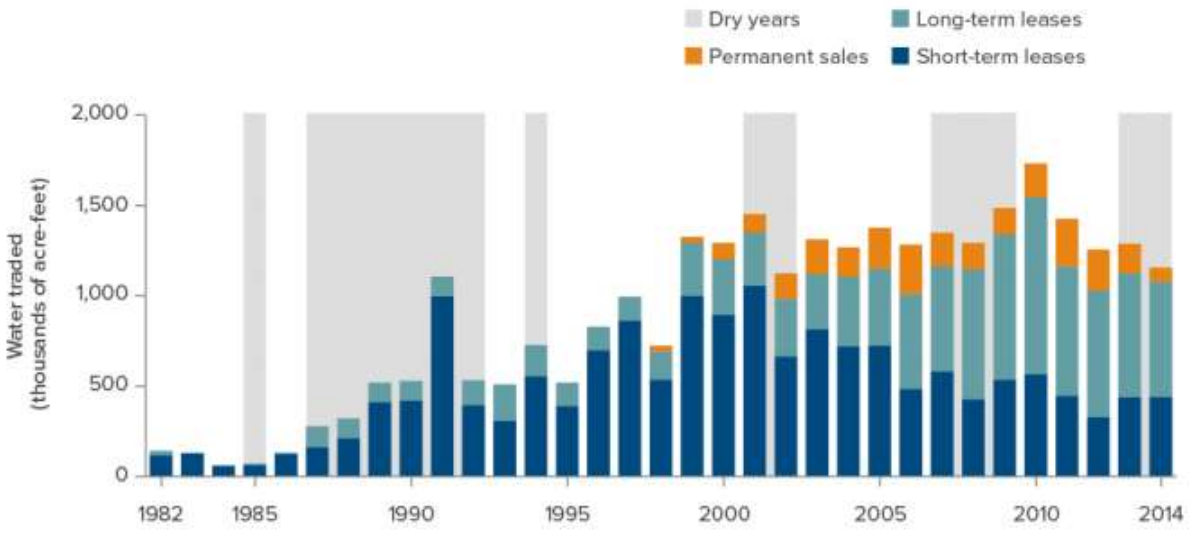

Figure 2: Water traded in the California water market. Source: [11].

3.2.3. Some shortcomings

Infrastructure and legal barriers hinder the California water market. As a result, trades among agencies that have rights to use water within the same large projects (CVP, SWP, and Colorado River) continue to dominate the market, accounting for over 60% of all trades since the mid-1990s, and 80 percent of trades not involving direct state or federal government purchases [9]. Less than 20% of the activity in the market can be attributed to the "open market": agencies within different projects or not belonging to projects at all.

The stagnation of the total amount of water market activity during the 21st century might also reflect the high transaction costs involved in the process. Some authors point out to the lack of clarity on priority beyond water rights [52], the need for different government roles [53], the lack of information on water rights, water available for trade, or prices [54], or the need for expanding some conveyance and storage capacity [55].

3.2.4. A win-win strategy: Option contract between Metropolitan Water District and Palo Verde Irrigation District

Metropolitan Water District (MWD) is the largest distributor of treated drinking water in the United States, supplying water to 19 million people in Southern California. It owns and operates an extensive water system and imports water from the Feather River, in Northern California, and the Colorado River to supplement local supplies. Palo Verde Irrigation District (PVID) provides water to more than 50,000 hectares of farmland in Riverside and Imperial Counties, with a water right from the Colorado River of 555 hm3.

In 2005, MWD and PVID signed a 35-year agreement to fallow annually between 2,400 and 107,000 hectares of PVID land, depending on MWD necessities. Farmers that participate agreed in fallowing between 10 and 35% of acreage per year, receiving an up-front payment of $3,170 per acre to participate in the program ($1283/hectare) plus an annual payment of $600 per acre fallowed each year. More than 90% of PVID landowners accepted to participate. Between 30,000 and 120,000 acre feet (37 to 148 hm^3) or water is made available to MWD customers annually [56].

A pilot program was developed initially between 1992 and 1994, when the utilities learned that 60 full-time agricultural jobs and an estimated $4 million lost in farm-related services,

prompting the establishment of a $6 million local development fund to mitigate the impact of the water transfer on the Palo Verde Valley [56].

Option contracts have emerged lately in other parts of California. This is a clear example that water reallocation can be a much cheaper option that supply infrastructure when dealing with temporal shortages, but also with structural deficit in supplies (see [57]–[59] for a more formal risk analysis).

3.3. Spain

3.3.1. Legal framework

With the declared objectives of providing flexibility to the Spanish system of public water use rights (concessions), increasing the economic efficiency of water use and reducing the economic impact of scarcity, the Spanish Parliament passed in 1999 the Water Law Amendment (Law 46/1999), which legislated and regulated the operation of water markets in Spain. Law 46/1999 allowed, subject to the application to and the authorization by the corresponding river basin authority, for the voluntary water trading between concession holders entering into a private agreement to temporarily transfer their water use rights for a price or "compensation", through what is referred to as a temporary lease contract [60]. Before this reform only private groundwater rights could be traded, ether leased or sold [30]. To maintain the public nature of water use rights, prevent speculation and protect the rights of third parties and the environment, Law 46/1999 established restrictions in the direction, volumes and spatial extent of the exchanges. For instance, water cannot be sold from consumptive to non-consumptive users and the other way around, from higher to lower priority users or to non-right-holders [30]. Inter-basin contracts are restricted to drought periods and to those basins that are already interconnected, requiring the authorization of the Spanish Government. The volume that can be sold is restricted to the real water consumption of the selling right-holder rather than the volume defined in the concession. Apart from lease contracts between users, Law 46/1999 provided for the possibility of river basin authorities setting up water use rights exchange centres to launch public water rights purchase offers to holders interested in temporarily or permanently transferring their water concessions, which would be transferred to other interested right-holders, in the manner of the water banks operating in the United States of America [61], [62].

3.3.2. Water trading experiences

The reader can find descriptions of the experiences with formal water markets in Spain in Calatrava and Gómez-Ramos [63], Garrido et al. [62], Rey et al. [30] and Palomo-Hierro et al. [12]. Garrido et al. [62]and De Stefano and Hernández-Mora [64] address the barely documented issue of informal water trade agreements, while Montilla-López et al. [65] does the same with water banks experiences. Calatrava and Martínez-Granados [60] and García-Mollá et al. [66] provide detailed descriptions of the functioning of water markets in the Segura and Júcar basin respectively.

The activity of water markets in Spain since they were formally regulated in 1999 has been limited, both in number of operations and volumes traded, clearly below what was initially expected in view of the characteristics of the Spanish water economy. Even in the driest years, exchanged water represent less than 1% of all annual consumptive uses [30]. Unsurprisingly, with some exceptions, most trading has concentrated in the southeast quadrant of Spain where most water-stressed areas are located [12]. Agricultural users have been the main water sellers, whereas, with the exception of a handful of large purchases by urban suppliers and the public buybacks of rights, a majority of water resources have been purchased by farmers.

Until the 2005, when a severe drought started and water markets became more active, the formal trading activity was very limited. In fact, only 46.66 GL were traded in Spain [12], 20 GL of which corresponded to a one-off purchase by an urban supplier and 10.1 GL to lease contracts within the Segura basin [63]. Later on, during the 2005-08 drought, the Spanish Government authorized inter-basin lease contracts using the existing transfer infrastructures, as an exceptional emergency measure to abate water supply problems in the hardest hit areas [62]. This resulted in several agreements between users from the Segura and Tagus basins (using the Tagus-Segura Transfer) and between users in the Almanzora and Guadalquivir basins (using the Negratín-Almanzora Transfer). These were annual agreements for specified volumes, at prices in origin that ranged from 0.15 to 0.28 €/m^3, involving a very small number of trading partners, and that were repeated with similar conditions during several years [30], [60].

The activity of intra-basin contracts, the only ones that functioned once the drought was over, increased in the period 2009-2014 with respect to 2000-2005. When a new drought situation recurred in 2014, the Spanish Government authorized again the celebration of lease contracts between users from different basins. However, in absence of published data for the whole country, the available evidence for the Segura basin, the major destination of inter-basin contracts, suggests that traded volumes have been significantly reduced with respect to those in the previous drought, partly because the Spanish Government is following a more strict application of the legislation [60].

Regarding they water exchange centres, they did not enter into operation, and only in the Guadiana, Júcar and Segura basins, until at the start of the 2005-2008 drought, when the Spanish Government reinforced their effectiveness by allowing them to cater for other demands, such as securing environmental uses. The water authorities of these three basins issued several public water rights purchase offers between 2006 and 2008, which had a limited success. In the case of the Júcar and Segura basins, all the purchased resources were used to maintain environmental river flows, but the budgets were not used up because there were not enough suppliers that met the set requirements and the purchase price was not attractive for farmers [30]. The aim of the Upper Guadiana water rights purchase offers, the largest-scale experience to date in Spain, was to raise the water tables in a severely over-exploited aquifer. In this case, the budget was fully allocated, but purchased rights were reallocated to other users in the form of new public concessions, and groundwater pumping was hardly reduced at all [62]. None of these water exchange centres has operated again.

Nationally the activity of water markets has been concentrated in drought periods [60]. The sources of most of the volumes traded are inter-basin lease contracts and public buyback of rights through water exchange centres. Palomo-Hierro et al. [12] estimate the total volume traded in Spanish water markets between 2001 and 2011 to be 590 GL, 81.5% of which took place during the three years drought in 2005-2008. Inter-basin agreements totalled 39.9% of the volumes traded in that period, while public water rights purchase orders and intra-basin lease contracts accounted for 26.5% and 33.6% of these, respectively. In addition to the reduced number of trading partners and operations, the traded volumes are insignificant, moreover if we compared them with those in countries with more active water markets. Even considering 2007, the year with the largest market activity, traded volumes amount to less than 1% of total water use in the country, far below Chile, Australia and even California, and similar to the South African Republic [12]. This figure rises up to between 2.5% and 4.5% for the most water scarce basins.

The available evidence also show that there is a considerable price spread in lease contracts [12], [30], even within the same basin and years [60]. Prices have ranged between 0.06 and 0.30 €/m^3 at source, net of transportation costs and losses. This, together with the relatively low number of market participants and transactions, suggests that there is a thin market, typical of situations where relevant barriers to trade exists [67], [68].

3.3.3. Barriers to trade

Several studies have pointed at some of the reasons for the limited functioning of water markets in Spain ([12], [30], [62], [69]–[71]; to cite a few). Many of the barriers to trade highlighted by these authors are similar to those in other countries, such as Australia, Chile or the USA: rigid legislation, spatial restrictions, slow administrative procedures, difficulties in finding trading partners, market thinness and price dispersion, etc. However, the evidence from these countries shows that their water markets are more flexible and that the traded are volumes relatively greater [30], [72], what suggests that barriers to trade could be more restricting in Spain.

In addition to the restrictive regulatory framework, the most relevant barriers to trade in Spain would be the lack of market transparency, the insufficient definition of the volumes potentially tradable, and the fact that the administrative authorization process is not only slow but its outcomes are uncertain. However, the major barrier is probably the increasing opposition of some stakeholders, including those in the areas-of-origin, environmental organisations, etc. [62], [70], what results in conflicts between different users and regions and political interferences. All these barriers to trade have resulted in thin markets with monopsonistic and monopolistic behaviours [70].

Most of the above cited studies coincide in the need of an improved and more flexible regulatory framework, similar to the reforms included in the 2010 Andalusian Water Act. Reforms should also include a clearer definition of tradable resources and criteria under which exchanges would be authorised, a more agile administrative process with more predictable outcomes, less political interferences and more transparency.

In addition, the Spanish Government should go beyond lease contracts between right holders and foster other trading mechanisms, especially in more water-stressed areas. For instance, water supply option contracts could reduce uncertainties and transaction costs [30], [71]. Similarly, using Water Banks for something else than very occasional environmental water buybacks could reduce transaction costs and increase market participation [65], while allowing for a better public monitoring of operations [62] and an increased market transparency [12].

Finally, these barriers to trade that constraint on the transfer of water rights result in the role of formal water markets being taken by the sale and lease markets for land with irrigation rights, and by informal water markets functioning mostly in the most water stressed southern and eastern areas [60], [62]. Informal water markets are those that are not covered by the provisions of Law 46, and that include exchanges between members of the same WUA (Water Users Association) and, to a larger extent, the lease and of private groundwater rights [64]. Their activity suggests that the current regulatory framework does not respond to the changing needs of water users, especially during droughts.

3.3.4. An overall assessment of the Spanish water markets experience

It would be far from true to consider the Spanish experience with water markets to date as a successful story, as there are both positive and negative aspects. Obviously, a positive issue is that water resources have been reallocated to higher value uses and to more water-stressed areas, thus generating ample gains in welfare, especially in the case of inter-basin operation [73]. Moreover, the water exchange centres briefly operating during the 2000s have provided environmental benefits through the public water rights purchase offers, which, like the public water banks of California, Australia or Canada, have been used exclusively to achieve environmental goals [61], [74]. However, the notable gains-from-trade of inter-basin operations may have been smaller due to the alleged environmental impacts in the basins of

origin of water and the indirect public financial support to during the 2005-2008 drought in the form of water tariff rebates [75].

Gains-from-trade may have outweighed possible negative environmental impacts, which, are yet to be quantified. There is still a disputed debate about this question [70], which results from the general lack of transparency in which Spanish water markets operate. From the reduced traded volumes and the fact that some applications have been rejected based on potential environmental impacts, we can assume that these have been insignificant for intra-basin operations. In the case of inter-basin leases, the environmental impacts may have been greater, although, as commented, this is a conjecture. However, in most operations, water authorities have required that a share of the exchanged volume be left in the watercourses of the area-of-origin [62], [70]. Another negative aspect is that the increasing opposition of some stakeholders has resulted in conflicts between different users and regions and political interferences (facilitated by the unsecured criteria for authorising trading operations).

In this sense, in our view, there might have been some political ambiguity towards water markets. The current regulatory framework gives water authorities a lot of leeway for political intervention. The Spanish Government played a relevant role by actively supporting inter-basin trading during the 2005 to 2008 drought [70], and promoted successive legal reforms aimed at extending trading opportunities [75]. However, they have not clearly committed to harnessing the potential of water markets. Moreover, the Spanish Government seems to be increasingly reluctant towards inter-basin lease contracts [60]. Should the Spanish Government decide to turn water markets into a more used and efficient tool, the instruments defined in the 1999 Water Act should be better designed and developed. Lease contracts needs more security and faster administrative procedures, while water banks should function permanently.

Despite the mixed picture, many experts and relevant stakeholders consider water markets as an useful tool to help water allocation in Spain, with potential to solve critical water scarcity situations, as long as they are adequately regulated and monitored, but far from being the solution to structural water scarcity problems in the country [62], and in no case a substitute for water authority action. Nevertheless, there is consensus in the need of deep reforms for water markets to provide their full potential without threatening the public interest [30].

4. What can we learn from our experience trading water?

In 1920 Alfred Marshall provided clarity to economic thought via the introduction of intersecting supply and demand curves to explain producer and consumer surplus. By illustrating how marginal utility changed demand and supply price elasticity, consumer and producer behaviour could then be explained. Markets are then a place where individuals interact in an attempt to maximise their utility over time. Marshall notes that markets can range in both size and structure from: open international market places; to ‘secluded’ where all external influence is frozen out; and the majority of markets that economist must study, lie somewhere between the two. Subsequently, markets are often considered as the panacea to economic problems. However, markets are not a naturally organic creation, markets are designed and this requires government intervention to deal with the complex problems of market failure and missing markets [76].Thus a single market can be used to ‘solve’ a myriad of social and economic problems, while acting as a clearance house to link buyers and seller together. Without a clear design, guidance, and rules of participation, markets can fail.

Apart from the MDB in Australia, in all countries where water markets have been established, trading activity remains relatively limited (typically 1-5% of allocated volumes). Water markets provide some flexibility, but their potential has been limited. Market limitations

are contextual and historic political and policy decisions (that frame the markets design, private and public participation, legal frameworks, and institutional structures) create a legacy of obstacles that inhibit swift reform. While this inability to enact reform benefits existing right owners, the time required to enact change, if utilised properly, can be used to obtain more information to design better markets and ultimately lead to a better outcome for society.

For markets to be established there needs to be political will [27]. The transition towards a closed basin, capping extractions, allocating property rights and putting markets into place can only occur if either the public sees the need for change and directs political action, or if the policy process is being done to improve welfare for society [77]. Each alternative has political costs and benefits, as political process is a game the absence of bipartisanship markets may never develop.

Several studies have provided insight towards identifying physical and institutional factors that are currently hampering the activity of water markets in different countries [19], [26], [62], [78]. Among these, the study of Marston and Cai [26] seems to provide the most comprehensive and updated review of the existing barriers. According to their research, the major difficulties faced in undertaking water trading schemes are:

- The lack of well-defined and enforceable water rights, mainly resulting from the existence of some financial, administrative and cultural factors which difficult the adoption of water reforms aimed at breaking the linkage between water rights and land rights.

- Third-party effects arising from water trading, i.e. the impact that water market transactions can have on users not directly involved in market decision-making processes or negotiations, or their social stability, or the environment (e.g. instream flows, water quality, area-of-origin equity…).

- The lack of information support and limited stakeholder involvement, which prevents potential water users from market participation, and therefore narrowing the market.

- Transaction and transition costs that may outweigh any difference in the marginal productivity of water between buyer and seller, hampering potential water transfers. Examples of transaction costs may include the cost derived from gathering information, identifying trading opportunities, negotiation, conveyance, monitoring, enforcement and third-party impacts mitigation; while transition costs correspond to those institutional costs to shift from the previous institutional structure to one more favourable to markets [79]. If transactions costs are greater than gains from trade, the transactions will not be profitable and will not take place [80], [81].

- Unsustainable institutional structure and operation including excessive or over restrictive regulations or rules that prevent water transfers to other uses or places.

In places where water markets have matured and expanded (e.g. Australia) there is growing interest in the potential for more flexible trading mechanisms (‘secondary markets’ as termed by the Australian NWC), such as water derivatives. Water derivatives (forward contracts, futures and options) have several economic, institutional and risk-related benefits in comparison with traditional water trading mechanisms. They are already being used in some countries, helping urban water suppliers to secure water for different uses, environmental regulators to guarantee minimum environmental flows during water shortage periods, and irrigators to plan their activities knowing that they will have water available later in the season. Several authors have also demonstrated the potential benefits of water derivatives for countries where they do not currently exist, like Spain [58], [82]–[84]. The implementation of these mechanisms increases the risk management alternatives available and reduces risk

management costs, enables water users to tailor water access to their requirements, and encourages more efficient utilisation of water rights and associated capital.

5. Concluding remarks

The review of successful water trading in different countries highlights the benefits of markets as a tool to reallocate water and contribute to solve water availability issues. However, as the presented case studies also show, in reality markets are far from perfect and must be carefully designed and implemented to release their whole potential and avoid negative externalities. Due to increasing water availability pressures and a shift from supply to demand-focused water management approaches, we believe water markets could play a more important role in water reallocation in the future in many countries, once the prerequisites for their implementation are met in those areas. Learning from existing systems, like we are doing here, could improve future market experiences and increase their success.

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References

[1] B. C. Bates, Z. W. Kundzewicz, S. Wu, and J. P. Palutikof, “Climate Change and Water. Technical paper of the Inter-Governmental Panel on Climate Change,” Geneva, 2008.

[2] J. J. Bogardi, D. Dudgeon, R. Lawford, E. Flinkerbusch, A. Meyn, C. Pahl-Wostl, K. Vielhauer, and C. Vörösmarty, “Water security for a planet under pressure: interconnected challenges of a changing world call for sustainable solutions,” *Curr. Opin. Environ. Sustain.*, vol. 4, no. 1, pp. 35–43, 2012.

[3] European Commission, “A Blueprint to Safeguard Europe’s Water Resources,” Brussels (Belgium), 2012.

[4] IPCC, “Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.,” Cambridge, UK, 2014.

[5] F. Molle, P. Wester, and P. Hirsch, “River basin closure: Processes, implications and responses,” *Agric. Water Manag.*, vol. 97, no. 4, pp. 569–577, 2010.

[6] A. Escriva-Bou, M. Pulido-Velazquez, and D. Pulido-Velazquez, “Economic Value of Climate Change Adaptation Strategies for Water Management in Spain’s Jucar Basin,” *J. Water Resour. Plan. Manag.*, vol. 143, no. 5, 2017.

[7] J. M. Sumpsi, A. Garrido, M. Blanco, C. Varela, and E. Iglesias, *Economía y Política de Gestión del Agua en la Agricultura*. Madrid (Spain): MAPA and Mundi-Prensa, 1998.

[8] D. H. Getches, “Water Wrongs: Why Can’t We Get It Right the First Time?,” *Environ. Law*, vol. 34, no. 1, 2004.

[9] E. Hanak and E. Stryjewski, “California’s Water Market, By the Numbers: Update,”

2012.

[10] S. Wheeler, A. Loch, A. Zuo, and H. Bjornlund, “Reviewing the adoption and impact of water markets in the Murray-Darling Basin, Australia,” *J. Hydrol.*, vol. 518, pp. 28–41, 2014.

[11] E. Hanak and J. Jezdimirovic, “Just the Facts: California’s Water Market,” 2016.

[12] S. Palomo-Hierro, J. A. Gómez-Limón, and L. Riesgo, “Water markets in Spain: Performance and challenges,” *Water*, vol. 7, no. 2, pp. 652–678, 2015.

[13] D. Adamson, A. Loch, and S. K, “Adaptation responses to increasing drought frequency,” *Aust. J. Agric. Resour. Econ.*, vol. 61, no. 3, pp. 385–403, 2017.

[14] R. Q. Grafton, C. Landry, G. D. Libecap, and J. R. O’Brien, “Water Markets: Australia’s Murray-Darling Basin and the US South West,” *Int. Cent. Econ. Res.*, vol. Working Pa, 2009.

[15] H. Bjornlund, L. Nicol, and K. K. Klein, “Challenges in implementing economic instruments to manage irrigation water on farms in Southern Alberta,” *Agric. Water Manag.*, vol. 92, no. 3, pp. 131–141, 2007.

[16] H. Bjornlund, “Efficient Water Market Mechanisms to Cope with Water Scarcity,” *Water Resour. Dev.*, vol. 19, pp. 553–567, 2003.

[17] E. Hadjigeorgalis, “A place for water markets: Performance and challenges,” *Appl. Econ. Perspect. Policy*, vol. 31, no. 1, pp. 50–67, 2009.

[18] D. Stickney, “Formal Water Markets: Global Examples and their Potential in Alberta,” 2008.

[19] M. E. Qureshi, T. Shi, S. E. Qureshi, and W. Proctor, “Removing barriers to facilitate efficient water markets in the Murray-Darling Basin of Australia,” *Agric. Water Manag.*, vol. 96, no. 11, pp. 1641–1651, 2009.

[20] D. Burdack, A. Biewald, and H. Lotze-campen, “Cap-and-trade of Water Rights,” pp. 318–326, 2014.

[21] B. Saliba and D. B. Bush, *Water markets in theory and practice: Market transfers, water values, and public policy.* Boulder, Colorado: Westview Press, 1987.

[22] M. D. Young and J. C. McColl, “Robust Reform: The case for a new water entitlement system for Australia,” *Aust. Econ. Rev.*, vol. 36, no. 2, pp. 225–234, 2003.

[23] K. W. Easter, M. W. Rosegrant, and A. Dinar, “Formal and informal markets for water: Institutions, performance, and constraints.,” *World Bank Res. Obs.*, vol. 14, no. 1, pp. 99–116, 1999.

[24] NWC, “Australian water markets: Trends and drivers, 2007-08 to 2009-10,” 2011.

[25] K. W. Easter, “Water markets: Opportunities and constraints,” in *Water policy and wate markets*, G. Le Moigne and K. W. Easter, Eds. Washington D.C.: The World Bank, 1994.

[26] L. Marston and X. Cai, “An overview of water reallocation and the barriers to its implementation. Wiley Interdisciplinary Reviews:,” *Water*, vol. 3, no. 5, pp. 658–677,

2016.

[27] A. Loch, D. Adamson, and M. Mallawaarachchi, “Role of hydrology and economics in water management policy under increasing uncertainty,” *J. Hydrol.*, vol. 518, no. A, pp. 5–16, 2014.

[28] NWC, “Water Markets in Australia: A Short History.,” 2011.

[29] E. Hanak, “A California postcard. Lessons for a maturing water market,” in *Routledge handbook of water economics and institutions*, K. Burnett, R. Howitt, J. A. Roumasset, and C. A. Wada, Eds. London, U.K.: Routledge, 2015, pp. 253–280.

[30] D. Rey, A. Garrido, and J. Calatrava, “Water markets in Spain: Moving towards 21st century mechanisms and approaches with 20th century regulations,” in *Water markets for the 21st century: What have we learned?*, K. W. Easter and Q. Huang, Eds. New York (US): Springer, 2014, pp. 127–147.

[31] V. Casado-Pérez, *The role of government in water markets*. Abidgon, Oxon: Routledge, 2017.

[32] D. Zetland, “Water markets in Europe,” *Water Resour. IMPACT*, vol. 13, no. 5, pp. 15–17, 2011.

[33] C. J. Bauer, “Bringing water markets down to Earth: The political economy of water rights in Chile, 1976-1995,” *World Dev.*, vol. 25, no. 5, pp. 639–656, 1997.

[34] R. C. Griffin, D. E. Peck, and J. Maestu, “Myths, principles and issues in water trading,” in *Water Trading and Global Water Scarcity: international experiences*, J. Maestu, Ed. Abidgon, Oxon: Routledge, 2013, pp. 1–14.

[35] A. Marshall, *Surprising Design of Market Economies*. University of Texas Press, 2012.

[36] Australian Bureau of Statistics, “Water and the Murray-Darling Basin - A Statistical Profile Australia 2000–01 to 2005–06: ABS Catalogue No. 4610.0.55.007,” 2008.

[37] G. Love, “Impacts of climate variability on regional Australia,” in *ABARE Outlook 2005 Conference*, 2005.

[38] R. Q. Grafton and J. Horne, “Water markets in the Murray-Darling Basin,” *Agric. Water Manag.*, vol. 145, pp. 61–71, 2014.

[39] C. Guest, “Sharing the Water: One hundred years of River Murray politics.,” 2016.

[40] Environment Australia, “The Council of Australian Governments’ Water Reform Framework,” 1994.

[41] Council of Australian Governments, “Intergovernmental Agreement on a National Water Initiative: Between the Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia, the Australian Capital Territory and the Northern Territory,” 2004.

[42] Commonwealth of Australia, “Water Act 2007. Commonwealth of Australia.,” 2008.

[43] L. Crase, B. Dollery, and S. O’Keefe, “Managing Environmental Water: Lessons in Crafting Efficient Governance Arrangements,” *Econ. Pap. A J. Appl. Econ. policy*, vol. 30, no. 2, pp. 122–134, 2011.

[44] N. Austin, “Waterfind Group opens California base,” *The Advertiser*, 2016.

[45] A. Marshall, *Principles of Economics*. London: Macmillan and Co, 1920.

[46] F. H. Knight, *Risk, Uncertainty and Profit Library of Economics and Liberty*. Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Co., 1921.

[47] S. Wheeler and J. Cheesman, “Key findings from a survey of sellers to the Restoring the Balance Programme,” *Econ. Pap. A J. Appl. Econ. policy*, vol. 3, no. 340–352, 2013.

[48] D. Adamson, “Restoring the Balance: Water Reform & the Murray Darling Basin Plan,” The University of Queensland, 2015.

[49] D. Mitchell, E. Hanak, K. Baerenklau, A. Escriva-Bou, H. McCann, M. Pérez-Urdiales, and K. Schwabe, “Building Drought Resilience in California’s Cities and Suburbs,” 2017.

[50] Governor’s Commission, “Governor’s Commission to Review California Water Rights Law: Final Report,” 1978.

[51] D. Zilberman, D. Dinar, N. MacDougall, M. Khanna, C. Brown, and F. Castillo, “Individual and institutional responses to the drought: the case of California agriculture,” *J. Contemp. Water Res. Educ.*, vol. 121, no. 1, 2011.

[52] B. Gray, E. Hanak, R. Frank, R. Howitt, J. Lund, L. Szeptycki, and B. Thompson, “Allocating Water in California: Directions for Reform,” 2015.

[53] V. Casado-Pérez, “Missing Water Markets,” *NYU ENVTL. LJ*, vol. 23, pp. 157–217, 2015.

[54] A. Escriva-Bou, H. McCann, E. Hanak, J. Lund, and B. Gray, “Accounting for California’s Water,” 2016.

[55] B. D. Newling, M. W. Jenkins, J. Lund, and R. Howitt, “Southern California water markets: Potential and limitations,” *J. Water Resour. Plan. Manag.*, vol. 128, no. 1, pp. 21–32, 2002.

[56] T. Doherty and R. Smith, “Water Transfers in the West: Project, Trends, and Leading Practices in Voluntary Water Trading,” 2012.

[57] K. Hansen, R. Howitt, and J. Williams, “aluing risk: options in California water markets,” *Am. J. Agric. Econ.*, vol. 90, no. 5, pp. 1336–1342, 2008.

[58] A. Gómez-Ramos and A. Garrido, “Formal risk-transfer mechanisms for allocating uncertain water resources: The case of option contracts,” *Water Resour. Res.*, vol. W12302, 2004.

[59] R. E. Howitt, “Spot Prices, Option Prices, and Water Markets: An Analysis of Emerging Markets in California,” *Mark. Water Potential Perform.*, pp. 119–140, 1998.

[60] J. Calatrava and D. Martínez-Granados, “Los mercados formales de agua en la cuenca del Segura,” in *Los mercados de agua en España: presente y perspectivas*, J. A. Gómez-Limón and J. Caltrava, Eds. Almería: Cajamar Caja Rural, 2016, pp. 251–281.

[61] J. B. Loomis, K. Quattlebaum, T. C. Brown, and S. J. Alexander, “Expanding Institutional Arrangements for Acquiring Water for Environmental Purposes: Transactions Evidence for the Western United States,” *Int. J. Water Resour. Dev.*, vol. 19, no. 1, pp. 21–28, 2003.

[62] A. Garrido, D. Rey, and J. Calatrava, “Water trading in Spain,” in *Water, Agriculture and the Environment in Spain: can we square the circle?*, L. Stefano and M. R. Llamas, Eds. CRC Press/Balkema, Taylor and Francis, 2013, pp. 205–216.

[63] J. Calatrava and A. Gómez-Ramos, “El papel de los mercados de agua como instrumento de asignación de recursos hídricos en el regadío español.,” in *La economía del agua de riego en España*, J. A. Gómez-Limón, J. Calatrava, A. Garrido, F. J. Saez, and A. Xabadia, Eds. Almería: Fundación Cajamar, 2009, pp. 295–319.

[64] L. De Stefano and N. Hernández-Mora, “Los mercados informales de agua en España: una visión de conjunto,” in *Los mercados de agua en España: Presente y perspectivas*, J. A. Gómez-Limón and J. Calatrava, Eds. Almería: Fundación Cajamar, 2016, pp. 95–121.

[65] N. M. Montilla-López, C. Gutierrez-Martin, and J. A. Gómez-Limón, “Water Banks: What Have We Learnt from the International Experience?,” *Water*, vol. 8, no. 10, p. 466, 2016.

[66] M. García Mollá, C. Sanchis Ibor, H. Macián Sorribes, L. Avellá Reus, and M. Pulido-Velazquez, “Los mercados de agua en la demarcación hidrográfica del Júcar,” in *Los mercados de agua en España: Presente y perspectivas*, J. A. Gómez-Limón and J. Calatrava, Eds. Almería, 2016, pp. 284–312.

[67] M. Saleth, J. B. Braden, and J. W. Eheart, “Bargaining Rules for a Thin Spot Water Market,” *Land Econ.*, vol. 67, no. 3, pp. 326–339, 1991.

[68] J. G. Tisdell, “Water markets in Australia: An experimental analysis of alternative market mechanisms.,” *Aust. J. Agric. Resour. Econ.*, vol. 55, no. 4, pp. 500–517, 2011.

[69] G. Ariño and M. Sastre, “Water sector regulation and liberalization,” in *Water Policy in Spain*, A. Garrido and M. R. Llamas, Eds. Taylor & Francis, 2009, p. 95-106.

[70] A. Garrido, J. Maestu, A. Gomez-Ramos, T. Estrela, J. Yague, R. Segura, J. Calatrava, P. Arrojo, and F. Cubillo, “Voluntary water trading in Spain: A mixed approach of public and private initiatives,” in *Water trading and global water scarcity: International experiences*, J. Maestu, Ed. Abidgon, Oxon: Routledge, 2013, pp. 180–193.

[71] A. Garrido, J. Calatrava, and D. Rey, “La flexibilización del régimen de concesiones y el mercado de aguas en los usos de regadío,” in *Usos del Agua (Concesiones, Autorizaciones y Mercados de Agua)*, A. Embid, Ed. Aranzadi – Thomson Reuters, 2013, pp. 177–197.

[72] R. Q. Grafton, G. Libecap, S. McGlennon, C. Landry, and B. O’Brien, “An integrated assessment of water markets: A cross-country comparison,” *Rev. Environ. Econ. Policy*, vol. 5, no. 2, pp. 219–239, 2011.

[73] J. Calatrava and J. A. Gómez-Limón, “Mercados de agua y eficiencia económica,” in *Los mercados de agua en España: Presente y perspectivas*, J. A. Gómez-Limón and

J. Calatrava, Eds. Almería: Fundación Cajamar, 2016, pp. 125–155.

[74] B. Docker and I. Robinson, “Environmental water management in Australia: experience from the Murray-Darling Basin,” *Int. J. Water Resour. Dev.*, vol. 30, no. 1, pp. 164–177, 2014.

[75] N. Hernández-Mora and L. Del Moral, “Developing markets for water reallocation: Revisiting the experience of Spanish water mercantilización,” *Geoforum*, vol. 62, pp. 143–155, 2015.

[76] D. W. Bromley, “Entitlements, missing markets, and environmental uncertainty,” *J. Environ. Econ. Manage.*, vol. 17, no. 2, pp. 181–194, 1989.

[77] W. W. Rostow, “The Stages of Economic Growth,” *Econ. Hist. Rev.*, vol. 12, no. 1, pp. 1–16, 1959.

[78] J. Zhang, “Barriers to water markets in the Heihe River Basin in northwest China,” *Agric. Water Manag.*, vol. 87, no. 1, pp. 32–40, 2007.

[79] M. W. Rosegrant and H. P. Binswanger, “Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation,” *World Dev.*, vol. 22, no. 11, pp. 1613–1625, 1994.

[80] S. Beare, A. Heany, and C. Mues, “Water rights, transaction costs and policy reform,” *Abare Conf. Pap.*, vol. 03.10., 2003.

[81] P. Martin, J. Williams, and C. Stone, “Transaction costs and water reform: the devils hiding in the details. Cooperative Research Centre for Irrigation Futures,” 2008.

[82] F. Cubillo, “Looking for efficiency through integrated water management between agriculture and urban uses (Review),” *Water Sci. Technol. Water Supply*, vol. 10, no. 4, pp. 584–590, 2010.

[83] D. Rey, A. Garrido, and J. Calatrava, “Assessment of irrigators’ preferences for different water supply risk management tools: option contract and insurance,” *Environ. Resour. Econ.*, 2015.

[84] D. Rey, J. Calatrava, and A. Garrido, “Optimization of water procurement decisions in an irrigation district: the role of option contracts.,” *Aust. J. Agric. Resour. Econ.*, vol. 59, pp. 1–25, 2015.