GLOBAL COMMISSION on the ECONOMICS OF WATER

TECHNICAL REPORT

Water Pricing, Costs and Markets

Sarah Ann Wheeler[1], Céline Nauges[2] and R. Quentin Grafton[3]

[1] Professor of Water Economics, School of Economics and Public Policy, University of Adelaide, Australia

[2] Research Director, French Institute for Research in Agriculture and Environment, Toulouse School of Economics, France

[3] Professor of Economics, ARC Laureate Fellow, Chairholder UNESCO Chair in Water Economics, Crawford School of Public Policy, Australian National University, Australia

Technical Report for the Global Commission on the Economics of Water. Convened by the Government of the Netherlands. Facilitated by the Organisation for Economic Co-operation and Development (OECD)

February 2023

watercommission.org

Acknowledgements

We give our deepest respects to their Elders, past and present, who have been and always will be the Traditional Custodians of Australia's waters including its aquifers, streams, and rivers. We acknowledge that Australia's Indigenous nations have long-standing cultural, social, environmental, spiritual, and economic values, rights and responsibilities with respect to their Country.

Maurice Nevile provided exemplary copy editing of two drafts of the manuscript and formatting assistance. Mai Nguyen greatly assisted with administrative support. Support with the final formatting, figures and proofing were provided by Cultivate Communications.

All errors and inconsistencies remain the responsibility of the authors alone.

Table of Contents

Executive summary

The allocation of water across space and time is a key challenge of water governance, especially so in a variable climate. Demand and supply are not always well matched, and deciding on who should receive water, and how much water, can be a difficult choice to make. Given that cost-effective supply augmentation projects are becoming more limited globally, increasingly water demand management strategies – and in particular water pricing and water markets – will need further exploration and development. This report is in two sections. The first half discusses the various principles associated with water pricing and costs and provides a set of recommendations to guide water pricing, and the second half describes formal and informal water markets, some case studies and finishes with a set of insights into further water market development.

Water pricing key findings

- A necessary principle for ensuring the viability of the water supply system is that water users should pay a price that reflects both direct and indirect costs of water consumption. This is known as the economic efficiency principle.
- Water is under-priced in most cases. Water price covers, at best, the physical supply cost, while environmental and resource costs are almost never properly assessed and accounted for.
- Remove or avoid subsidies that promote increased water extraction or water pollution.
- Water conservation and equity objectives lead to distortion of price signals.
- Water tariffs cannot achieve simultaneously several objectives.
- Affordability should be addressed using complementary instruments, such as vouchers, cash transfers or rebates. Equity issues should not be addressed by providing water for free.
- PPPs cannot solve all problems faced by water utilities, though they may have helped in reducing non-revenue water and improving operational efficiency.
- Water demand responds to price changes but is commonly found to be inelastic to its price.

Water markets key findings

- Informal water markets exist in many places around the world and are much more common than formal water markets.
- Formal (temporary and permanent) water markets are found in both rural and urban settings but are more prevalent in rural settings. They exist for both surface water and groundwater markets, for quantity (e.g. volumes traded) and quality (e.g. water salinity and nutrient pollution).
- Markets allow for flexible reallocation, represent voluntary trade and help elucidate the real opportunity cost of water.
- Water trade leads to three types of efficiency: allocative, dynamic and productive, with much empirical evidence suggesting significant net benefits.

- Water markets are not a panacea and require complex governance and institutional frameworks to oversee and regulate.
- Initial property right distribution matters and preferably equity issues should be addressed before establishing formal markets.
- Where formal water markets cannot be established due to governance or transaction cost issues, informal water markets or trade can be beneficial.

Acronyms

BoM	Bureau of Meteorology
CAPEX	capital costs
EU	European Union
IBNET	International Benchmarking Network for Water and Sanitation Utilities
IBT	increasing block tariffs
LRMC	long run marginal cost
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
PPP	Public Private Partnerships
SEEA-Water	System of Environmental-Economic Accounting for Water
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNICEF	United Nations Children's Fund
WFD	water framework directive
WHO	World Health Organisation

1 Introduction to water demand management

Water is allocated across many competing purposes. Irrigation water used in the agricultural sector accounts for about 70% of water use worldwide (Grafton and Wheeler, 2015). The remainder is used for industry and energy production – primarily the cooling of power plants – as well as supplying water to households, small businesses and other establishments (e.g. hospitals, schools, etc.) connected to the public supply system. In Europe, along with most OECD countries, the proportion of total water allocation used by agriculture is around 45%, with 40% allocated to industry and energy production, and 15% for public water supply (Gruère and Shigemitsu, 2021).

There is range of tools available to policy makers to manage such allocations which, very broadly, can be categorised under water supply augmentation and water demand management (Wheeler and Xu, 2021). Supply augmentation – namely engineering solutions (otherwise known as "hard" approaches) to increase water supply (e.g. irrigation infrastructure, dam and weir construction) or substitution (e.g. desalinated water) – has historically been the most promoted, given it offers a technical and relatively rapid method to address water scarcity (Hall et al., 2014). Supply augmentation can also occasionally be efficient where there are low marginal costs (Grafton et al., 2017). Water demand management strategies include regulatory and/or planning processes (e.g. legislation and regulation); educational measures (e.g. information and campaigns); planning (e.g. multi-stakeholder partnerships and causal risks-processes) and economic incentives (e.g. economic pricing, subsidies and/or property right changes that enable water markets). Ideally, both supply and demand responses should be integrated to address water security, however this is seldom the case (Griffin, 2006; Sadoff et al., 2015; Barbier, 2019).

Water tool options, and the ability to implement various strategies and planning processes, will differ by location. The "ladder of water tool interventions" available country by country, or region by region, will necessarily differ according to the resources and timeframes available, and institutional and personnel capability. In a poor region or country where there is very limited budget and data, the priority focus would be to develop the "first rung", namely institutional capacity to further understand water allocations, and sustainable use, to be able to inform and improve water allocation. In countries with large institutional capacity and knowledge, more ambitious intervention is possible and could therefore include developing both efficient and equitable water pricing and water markets in both rural and urban areas. The key point is that a three-step approach frames the nature and type of action or intervention by focusing on capacities, risks and options in a participatory process (Grafton et al., 2017).

The allocation of water across space and time is a key challenge of water governance, especially so in a variable climate. Access in many countries is determined by location (e.g. upstream); priority or first access rights; and sometimes money (e.g. those with the largest groundwater pumps for groundwater). Demand and supply are not always well matched, and often some high priority uses of water (such as safe drinking water) are not satisfied; similarly, ecosystem services can also suffer (Vörösmarty et al., 2010). With the choice of cost-effective supply augmentation projects becoming more limited globally, increasingly water demand management strategies – and in particular water pricing and water markets – will be further explored and implemented to address water scarcity and quality issues (Wheeler and Xu, 2021). Deciding on who should receive water, and how much water, can be a difficult choice to make, especially in situations such as within an industry (e.g. cotton grower versus dairy farmer?). This is where economic incentives can play a part. We discuss water pricing and fee principles first in this report, and then move onto water markets as a mechanism to reallocate water.

2 Water pricing and costs

2.1 Principles and components

All types of water use involve some costs. Water users should pay a price that reflects both the direct and indirect costs of their water use. This is known as the *economic efficiency* principle. Water that is pumped directly from raw water sources (either groundwater or surface water) for irrigation requires investing in a pumping system and paying for electricity to run the water pump. Delivering water to households and other services/businesses connected to the public water supply system involves a) fixed capital costs (building a network and pumping, treatment and storage facilities); and b) variable costs that depend on the volume of water that is treated and delivered (billing, collection etc.). The latter are commonly known as operation and maintenance costs or OPEX. For a water service to be viable, the price that is charged to water users connected to the public supply system should cover OPEX as well as future capital costs (otherwise known as CAPEX) which include the building and maintenance/renewal of new infrastructure (pipes, pumping and treatment plants, storage facilities).

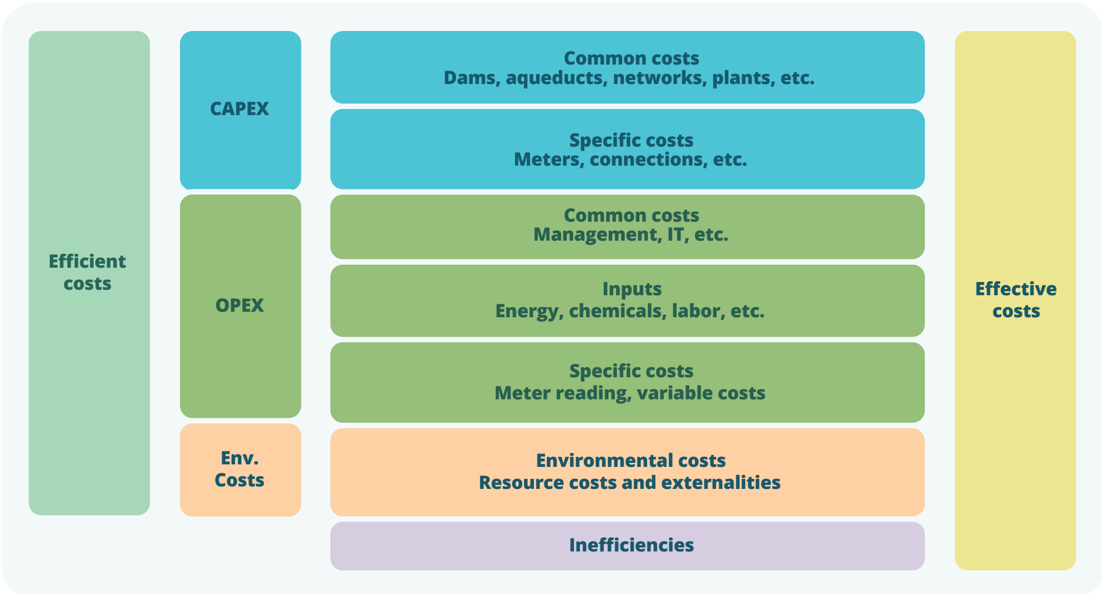
All types of water use generate externalities on other water users, first by exerting pressure on the raw water sources, and second by degrading its quality. For example, part of the water that is pumped returns to the ground, however, water that has been used for agricultural purposes may carry pesticide residues or nutrients, as well as livestock effluents. In addition, water that has been used for cooling power plants is much warmer when returned to the environment. Urban water uses lead to the discharge of wastewater that needs to be treated before being returned to the environment. The presence of these externalities, that is, those (indirect) costs imposed on others and on the environment, justify public intervention and the implementation of policy instruments (taxes, charges, command-and-control, etc.).

Taxes or charges are common instruments to make users internalise the costs they impose on others, including the environment. The recovery of indirect costs imposed on others and on the environment is explicitly stated in Article 9 of the European Union (EU) Water Framework Directive (WFD - 2000/60/EC). It requires member states to take account of the principle of recovery of the costs of water services, *including environmental and resource costs*. This directive led to the implementation of water pollution and water abstraction charges/taxes in EU member states, with the aim of making water users internalise the (indirect) costs of their water use. A more detailed discussion of principles and actual implementation of abstraction and pollution taxes/charges is provided in Appendix A (Figure A.1), along with some illustrative examples.

The multiple costs of water and sanitation service provision – and hence the multiple components that should translate into the price ultimately paid by water users – are summarised in Figure 2.1 below, reproduced from Andrés et al. (2019). This clearly identifies the three main cost components: operation and maintenance expenditure (OPEX), capital expenditure (CAPEX) and environmental and resource costs.

Effective costs embed all costs that are necessary for water service provision, including CAPEX, OPEX and environmental costs but also hidden costs induced by non-optimal management of resources. Hidden costs can take the form of extra capital expenditure required to increase production to make up for water production losses, or extra labour costs induced by the employment of unnecessary/useless staff. These extra costs are labelled as inefficiencies in Figure 2.1. *Efficient costs*, on the other hand, are minimum costs that would allow reaching the same level of service provision if the utility was using its available resources at best, that is, if the provision of water services was completely free of inefficiencies.

Figure 2.1 Costs of water service provision



Source: Andrés et al. (2019, p.24)

Key messages

- The bulk of water used worldwide is for irrigation purposes by the agricultural sector.
- All types of water use involve direct and indirect costs.
- Indirect costs are costs imposed on others by exerting pressure on the raw water sources (opportunity cost) and environmental costs induced by water abstraction and pollution.
- A necessary principle for ensuring the viability of the water supply system is that water users should pay a price that reflects both direct and indirect costs of water consumption. This is known as the *economic efficiency principle*.

2.2 Complexities in implementing water pricing principles

The economic principle that the price of water should be set such that all costs are covered (discussed above) aims to preserve the viability of the water supply system and infrastructure, and supplying good quality water to all households, while preserving water resources and the environment by sending the right signals to water users. However, its actual implementation faces four important hurdles:

- Most economists recommend that water be priced based on Long Run Marginal Cost (LRMC), that is, the cost of supplying an additional unit of water considering that the capacity of the system can vary (i.e. not assuming constant capacity as under short-term marginal cost pricing). The calculation by the utility/water provider of fixed and variable costs in the long run is difficult since it relies on projections of demographics, future water demand for all types of uses, future energy prices, availability and quality of raw water etc. There is uncertainty around such projections, in particular groundwater recharge and future demand are highly uncertain in a context of climate change. For a recent discussion on water supply risk and dynamic water pricing, see Chu and Grafton (2021).
- The valuation of indirect costs imposed on other users (opportunity cost) and on the environment (environmental cost) is difficult since most environmental goods are not traded and do not have any market value. Regulations imposed to account for environmental and resource costs induced by water abstraction and usage are often silent on how to estimate/measure them. See Appendix A for further discussions on environmental and resource costs.
- Water pricing is a sensitive political issue due to the nature of the good. Since water is not just a traded good but also a human right, water pricing often raises political acceptability problems. Governments are sometimes reluctant to increase water prices, and some population groups may put pressure on governments to keep prices low.
- Other objectives imposed by local or national governments, such as water conservation, equity among poor and rich households, and affordability (that is, household water expenditure as a share of income should not exceed a specific threshold) may complicate further price setting and distort price signals. In particular, Increasing Block Tariffs (IBTs), in which the volumetric price of water increases with the amount of consumption, have been increasingly popular. They are commonly advocated as the best instrument to achieve both water conservation and redistribution between rich and poor households. However, this is usually not true. See Section 2.4.2 for further discussions on the poor performance of IBTs in targeting subsidies (low prices) to the poor.

For all the above reasons, the price of water varies significantly across places and across industries. Some statistics on average water prices across the globe are shown in Appendix Table A1, illustrating wide geographic disparity. The price of water is also, in most cases, below actual marginal cost, or close to the short-term operation cost but still far from long-term marginal cost considering financing of existing and future water infrastructure. Also, price rarely reflects costs imposed on others and on the ecosystem, hence both the cost recovery and economic efficiency (sending the right signals to water users) objectives are only rarely fulfilled.

The necessity to send accurate signals to water users, in particular on the value of freshwater, will become increasingly prevalent in view of the more frequent and severe droughts that are likely to occur worldwide. Climate change is aggravating water threats and, in the context of a growing global population, will exacerbate competition between cities and agriculture for scarce water. Scarcity value is almost never considered in the price of water, which covers, at best, the physical cost of its supply. Even if countries from the European Union are required to levy water abstraction charges (cf. Article 9 of the EU Water Framework Directive discussed above), they are more in the nature of administrative fees and are usually not assessed based on the economic value of the water being withdrawn (Hanemann, 2005). Without any significant effort from governments and utility managers to account for the environmental and resource costs of water abstraction, the freshwater ecosystems will be under serious threat and conflicts between water uses will exacerbate.

The problem of underpricing of water is highlighted as one of the major contemporary challenges, in a number of recent articles and reports (Grafton et al., 2020; Andrés et al., 2021; Barbier, 2022). See also Section 2.4.1 for further discussions on the consequences of water underpricing.

Key messages

- The economic efficiency principle and the cost recovery objectives are rarely fulfilled in practice.
- Future capital costs, environmental and resource costs are difficult to estimate.
- There exists strong political pressure to keep water prices low.
- Water is underpriced in most cases. Water price covers, at best, the physical supply cost, while environmental and resource costs are almost never properly assessed and accounted for.
- Water conservation and equity objectives lead to distortion of price signals.

2.3 The multiplicity of water tariffs

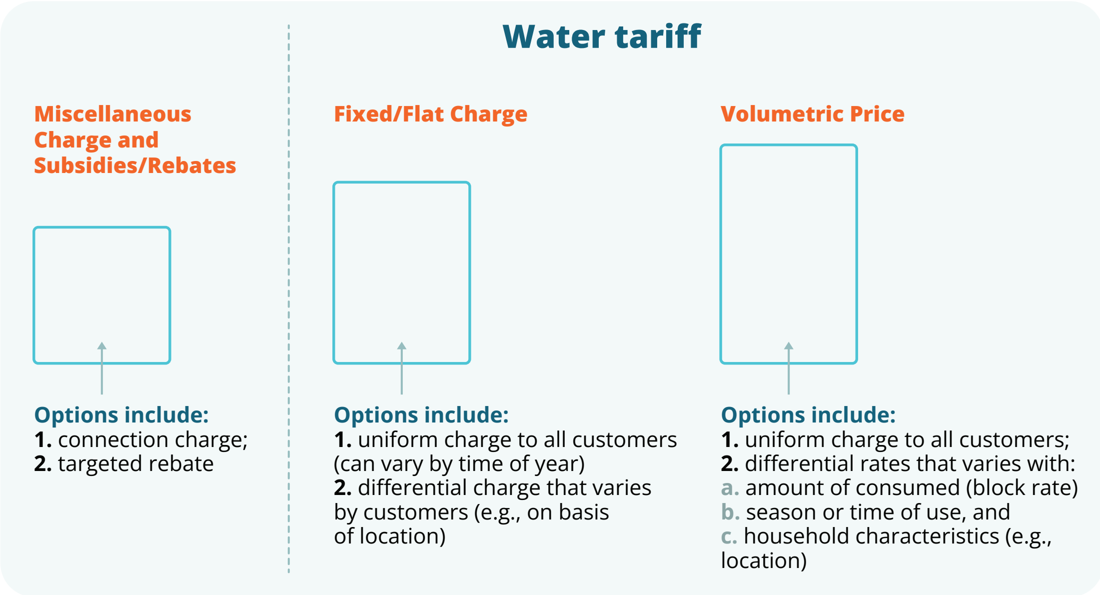
As discussed above, governments and/or utility managers often aim at setting water tariffs that would achieve multiple objectives. In addition to cost recovery, the objectives of equity and affordability are often claimed as priorities. Since it is well known that a single instrument cannot achieve multiple objectives (also known as the Tinbergen rule; cf. Tinbergen, 1952), we commonly observe that complex water tariffs fail in one or more dimensions. Tariffs are usually differentiated by type of use: residential (households), industry, small businesses and local public services (schools, hospitals etc.). In what follows, we present tariffs that are more commonly used for households. Several water tariffs co-exist, from very simple to very complex ones:

- **Flat charge only:** even if increasingly less common, water is sometimes charged at a flat rate regardless of the quantity of water used. This type of tariff was popular in places where water was abundant and/or where water was not metered, but it is now increasingly less common. This tariff is very simple and guarantees a fixed revenue to the service provider, but flat rates do not send any price signal to water users who pay the same fee whatever the quantity of water they use.

- **Two-part tariff:** the combination of a flat charge (or fixed fee) and a single volumetric price well reflects both the fixed and variable costs of water provision. It provides a signal to users that provision of water services includes a fixed cost (or service access fee including meter reading, billing, etc. that do not depend on water use), and variable costs that depend on the quantity of water used. A uniform price implies that users pay the same price for each cubic meter they consume. Since the total amount they pay depends on the volume of water used, this tariff should provide incentives to conserve water, and is still relatively simple for users to understand. If the volumetric price is set at the marginal cost, this tariff is economically efficient.
- **Flat charge + non-uniform volumetric price:** These types of tariffs still include two main components; however, the volumetric price is no longer constant. One common type of such tariff is the Increasing Block Tariff (IBT) where the volumetric price varies depending on the amount of water used (block rates). An increasing [decreasing] block tariff features volumetric prices that increase [decrease] with the amount of water used or the block of consumption. These tariffs have become very popular, especially in developing regions (see Figure 2.5 in Andrés et al., 2021, showing that about 50% of water utilities surveyed in the International Benchmarking Network for Water and Sanitation Utilities, or IBNET, use IBTs). IBTs have been described, wrongly, as being able to address simultaneously several objectives, including cost recovery, equity, affordability and water conservation. There is a widespread belief that low-income households consume low volumes of water and hence will benefit from subsidised prices in the first (or lifeline) block. Low prices in the lifeline block will be compensated for by higher prices in the higher blocks where richer households are located. However, low-income households are not always small consumers, especially if they have large family sizes and/or share a connection with other households. We will discuss further evidence of unexpected impacts of IBTs later.
- **Volume-differentiated tariffs or jump tariffs:** These tariffs are less common. In this case, all units of water are charged at the price of the highest block that has been reached. Such a tariff can lead to significant jumps in the water bills when moving from one block to the next.

Complex tariff structures involving several blocks are difficult to design. They require choosing the limits of each block and the price charged in each block. Inappropriate design can lead to inaccurate targeting and to households who are not in great need benefiting from subsidised water prices. Other elements can be added to the tariff, such as prices that vary by season, by location, or based on households' characteristics. Other measures can also be put in place to guarantee the affordability of water services. These measures can take the form of vouchers or rebates on the water bill for the poorest households. Their implementation requires that such households can be easily identified (Grafton et al., 2020). The various forms that water tariffs can take are summarised in Figure 2.2 below.

Figure 2.2 Various forms of water tariff



Source: Grafton et al. (2020, p. 95)

Key messages

- Water tariffs cannot achieve simultaneously several objectives.
- There exists a multiplicity of water tariffs, from very simple flat rate tariffs to highly complex (multiple blocks) tariffs.
- IBTs are the most popular water tariff, despite evidence of poor targeting performance.
- Affordability should be addressed using complementary instruments, such as vouchers or rebates.

2.4 Actual tariff implementation and consequences

2.4.1 Costs are not fully recovered

In very rare cases does the price of water reflect the long run marginal cost of providing water. Achieving the economic efficiency objective is difficult because of i) the difficulty in estimating long-run marginal cost and in valuing environmental water services, ii) price signal distortions induced by complex tariff schemes supposedly aimed at encouraging water conservation and improving equity and affordability (see Section 2.4.2), and iii) taxes/charges exemptions following political/lobbying pressures.

In a study for the World Bank using information collected on utilities around the world and gathered in the International Benchmarking Network for Water and Sanitation Utilities (IBNET) database, Andrés et al. (2019) studied in detail the problem of water underpricing and the misallocation of subsidies. They note (page 2–3): “Subsidies are a subset of funding flows between governments, service providers and customers. Subsidies occur when a user/customer pays less for a product or service than the service provider’s cost, leaving a third party (e.g. government, other users, future generations) responsible for covering the difference." Andrés et al. (2019) found that only 35% of the utilities found in IBNET are able to cover their operation and maintenance (O&M) costs of service provision and 14% the total economic cost, i.e. O&M and future capital costs.

It is also important to emphasise that achieving full cost recovery is even more complicated when utilities suffer from significant cost inefficiency due, for example, to a high level of water losses (due to poor maintenance of pipes for example) that translates into high non-revenue water. In developing countries, it is also not rare that utilities are overstaffed, which unnecessarily increases costs. Inefficiencies in utilities' operation and management make it more difficult for utilities to recover their costs. If, in addition, the quality of the water service is poor, then households may be reluctant to pay their bills or to pay higher bills, and prices cannot easily be increased. Such a vicious circle usually requires governments to make transfers paid from the general budget to the utilities to compensate for the deficit in revenues. Such a situation also discourages foreign investors. This problem is exacerbated in developing economies where there is high political pressure to keep water prices low.

Key messages

- Because water is sold at a price that is below marginal cost in most cases, costs are not fully recovered.
- Without full cost recovery, the viability of a water supply system is at risk.
- Low prices and under-investment in the maintenance of existing assets and building of new infrastructure may lead countries into a poverty trap.

2.4.2 Tariffs often fail to achieve equity objectives

Equity is concerned with the fairness of the allocation of resources across a given population. Commonly, equity translates into the principle that all users should have access to safe and reliable water, and that users in similar situations should not be charged differently for water. However, for the specific case of water, equity in water pricing is usually paired with the notion of affordability. That is, for some equity to be preserved among income groups, it is usually accepted that the proportion of income that is devoted to pay for water should not be disproportionately larger for low-income households and should not be above a specific threshold. Percentages from 2% to a maximum of 5% of total household expenditure have been commonly considered (Reynaud, 2016). For OECD countries, the share of water expenditure in income is often below 2% for the average household (Grafton et al., 2011; Reynaud, 2016; Ambec et al., 2016). However, this ratio is likely to be above 2% for the poorest households in some countries. Others argue that some groups in society should not pay anything for water, that they should receive water for free. However, the problem is that such a situation removes any incentives to conserve or be careful with water, and hence overuse/waste may have an even more detrimental impact on some user groups in areas where water is scarce. Hence, providing water for free is not recommended, and certain user groups should be compensated by other means.

This section discusses inequality and inequity issues between user groups, piped and non-piped households, and IBT issues.

Inequity between user groups

There is a sense of inequality between different groups of users. Residential water represents a smaller share than industry water and irrigation water, but households often face higher prices and charges. Even if irrigation water should be priced following cost recovery principles, the price charged to farmers and the abstraction/pollution charges they have to pay are in most cases much lower than what is imposed on residential consumption. This is the case in most European countries where irrigation water is usually charged at very low prices, while irrigation water can represent more than two-thirds of total water abstraction in some countries (OECD, 2010).

A survey was conducted by the OECD in 2019 on agriculture and water policies. Responses were gathered from a total of 38 countries (Gruère et al., 2020). Results indicate that pricing is used by 44% of the surveyed countries as the main tool for managing agricultural water, while 59% implemented quantitative regulations. Five countries (Australia, Chile, Mexico, Spain and the United States) use market mechanisms (see Section 3 for detailed discussions on water markets). However, survey results also showed that water abstraction is fully or partially metered, monitored or reported, in less than half of the responding countries. As far as water quality is concerned, Gruère et al. (2020; page 18) stated: "To protect and promote sustainable use of water-related ecosystems in and around agricultural areas, 85% of responding countries have set regulatory frameworks and 79% use support payment schemes. Agri-environment-climate measures under the EU's Rural Development Programme 2014–2020 included support payment programs for protecting selected natural habitats for organisms that are dependent on water. Beneficiaries voluntarily undertake five-year commitments to implement certain requirements that lead to habitats' protection."

In addition, some agricultural policies (for example policies linked to production or inputs such as water and energy) may encourage the use of irrigation water in a way that dampens the efforts made to encourage water conservation and protection of the environment. Among other examples, the subsidisation allocated to power generation in some Indian states have contributed to over-pumping of groundwater by farmers, leading to irreversible damage on some aquifers (Sayre and Taraz, 2019). It is too often the case that agricultural policies are designed without sufficient consideration regarding unintended consequences on the environment, and in particular freshwater resources. Policies incentivising land conversion, in particular the drainage of peatlands, may impact future freshwater availability. Policies that support the production of specific crops may induce farmers to use greater quantities of water-polluting chemical inputs. In a context of increasing population and food needs, it is crucial that farmers receive accurate signals to increase water use efficiency and improve water management. One necessary condition for farmers to receive an accurate signal on the value of the resource, and for a sound management of irrigation water in places where water is scarce, is the metering and monitoring of irrigation water. When irrigation water is not metered, water may be charged and/or allocated on a per hectare basis. If irrigation water is underpriced and water is charged or allocated based on land area, then the wealthiest farmers (who own larger farms) will be the primary beneficiaries of the subsidies. So, cost recovery and efficient and sustainable management of water resources in the agricultural sector are still far from being achieved.

Inequity between piped and non-piped households
In developing economies where all households do not have access to piped water, water pricing and water use are characterised by inequity among different household groups (piped versus non-piped households). There exists evidence that households relying on non-piped sources usually pay an average price that is higher than what is paid by households relying on piped water (Andrés et al., 2021). This may happen for several reasons.

Firstly, non-piped households who share access or communal standpipes may be collectively responsible for paying the water bills. If several families share a single tap or standpipe, the overall consumption may be quite large compared to the average consumption of individual households. If water is charged through an IBT, and if consumption falls in the higher blocks of the tariff structure, then the volumetric price may be much higher than the average price paid by individual households. Secondly, shared taps or standpipes are also likely to suffer from free riding or water stealing problems if no one controls water use. Finally, the price that is ultimately paid at a standpipe or kiosk also depends on the type of management. If management is under the direct responsibility of the water utility, then the price may be kept low. However, if the management is delegated to, or managed by, a private individual who does not face any specific control or regulation, then there may be a temptation to gain some mark-up above the actual formal price. Nowadays, prepaid meters and water ATMs (water vending machines) are installed in order to avoid markups charged by intermediaries (Andrés et al., 2021). The problem of unregulated water prices may also affect rural areas where informal markets develop and vendors deliver water in containers (jerry cans for example) to individual households, especially if there is not much competition between vendors. Section 3.1 provides additional information about informal water markets.

Access to non-piped sources may also require spending time walking to the source and waiting. The time cost may be substantial for some households. The relatively high price/cost of non-piped sources thus imposes some rationing on water use by the poorest households, hence there is significant inequity in water use between the poor and the rest of the population.

Inequity between income groups
To preserve equity between income groups and to preserve fairness in access to water as a basic need, low-income households should not spend for water a disproportionately larger share of their income. A simple volumetric tariff that applies to all households may not preserve affordability, especially if the volumetric price of water is set efficiently. Consequently, other instruments have to be used in conjunction to reduce the burden of water bills for low-income households. Targeted cash transfers or rebates for the low-income households should be preferred, rather than complex tariff schemes such as Increasing Block Tariffs (IBTs) (Nauges and Whittington, 2017).

To preserve equity, a number of utilities have implemented IBTs in which higher volumetric prices are charged above some consumption threshold. Such tariff schemes are claimed to make high users (assumed to be richer) cross-subsidise water consumption of low users (assumed to be poor). However, there is evidence that IBTs almost always fail in targeting subsidised prices to the poor (Whittington et al., 2015; Fuente et al., 2016; Nauges and Whittington, 2017). Nauges and Whittington (2017), using simulation tools, found that IBTs cross-subsidisation scheme works under two conditions: i) the price of water that is charged in higher blocks is higher than the marginal cost, in order to compensate for the price of water that is charged in lower blocks and is below marginal cost; and ii) households whose consumption falls in the higher blocks have to be richer than households who consume in the lower blocks. These conditions appear to be rarely observed in practice, which explains why wealthier households often get a larger share of the subsidies. Andrés et al. (2019) assess the performance of consumption subsidies for piped households in ten countries: Ethiopia, Mali, Niger, Nigeria, Uganda, El Salvador, Jamaica, Panama, Bangladesh and Vietnam. In most cases, households' water consumption is charged through an IBT structure. The main finding was the following (page 32): "In the 10 countries we analysed, an average of 56% of subsidies reach the wealthiest quintile of a country's population, while a mere 6% reach the poorest quintile."

Subsidies that intend to be provided through tariff design are only targeted at piped households. However, close to 30% of the world's population is still without access to safely managed drinking water (WHO and UNICEF, 2017). There is thus a large part of the world population which does not yet have a safe access to water and is thus excluded from subsidies distributed to piped households through tariffs (Komives et al., 2005; Banerjee et al., 2010; Angel-Urdinola and Wodon, 2011; Barde and Lehmann, 2014). Rather than complex tariff structures that often fail to achieve the equity objective, since they benefit more the wealthiest households in most situations, we recommend simpler tariffs, that is, single volumetric price set as close as possible to marginal cost + fixed component to cover fixed costs, combined with *transfers* to targeted (poorest) populations.

Transfers can take the form of tariff rebates, that is, low-income households receive direct cash transfer to cover part of their water bill, or vouchers which allow them to receive a portion of their water consumption at a subsidised rate or even for free. The main difficulty is targeting, i.e. identifying eligible recipients. Water utilities rarely have information on household size or household income, so such schemes may be better managed by social welfare agencies.

Key messages

- Differentiated tariffs and exemptions often generate inequity between user groups.
- The agriculture industry often pays a lower price than households, even when they abstract most of the water and generate environmental and resource costs.
- Remove or avoid subsidies that promote increased water extraction or water pollution.
- Inequity exists between piped and non-piped households, with piped households benefiting more from the subsidies to the water supply system.
- Non-piped households who use share taps or standpipes, or rely on private vendors, may be charged a higher price than households connected to the piped system.
- Equity issues should not be addressed by providing water for free.
- Inequity between income groups and affordability issues are usually not solved with complex tariff schemes. Targeted cash transfers or rebates offered to low-income households are preferable.

2.5 Public-private partnership as a solution to water underpricing?

A number of Public Private Partnerships (PPPs) were put in place in the water and sanitation sector in the 1990s, with great hope for their ability to expand piped water coverage and to solve water utilities' under-financing problems. PPPs were seen as a way to benefit from new investment, new technology and expertise, for a sector that was too often reliant on subsidies and transfers from governments, and that was plagued with inefficiencies.

Hence, there was a spectacular increase in the number of developing and transition countries developing such partnerships in the 1990s: the population served by private operators increased from 6 million to 94 million over the decade (Marin, 2009). However, following partnership failures and contract terminations in some countries, doubts about the PPPs model and performance started to emerge in the early 2000s, which led to a slowdown in the number of signed contracts in that decade. Marin (2009; p. 2) followed two decades (1990–2009) of PPPs in the water sector and found that: "out of the more than 260 contracts awarded since 1990, 84% were still active at the end of 2007, and only 9% had been terminated early. Most cancellations were in sub-Saharan Africa, a challenging region for reform, and in Latin America, among concession schemes." Marin's (2009) main findings included:

- the outcome in terms of the expansion of piped water coverage in cities managed by PPPs remained below expectations, and a sizeable share of the coverage expansion was not financed by the private operators (but by public revenues or tariff revenues);
- PPPs helped reduce water rationing and improved continuity of service in most cases;
- PPPs helped improve operational efficiency by reducing (commercial) water losses and improving collection ratio and labour productivity (staff has been reduced in a number of utilities operating in Latin America); and
- in most cases PPPs led to tariff increases.

Assessing the impact of PPPs on water tariffs is difficult. On the one hand, improvements in operational efficiency may induce a decrease in water prices. On the other hand, since water is underpriced in several utilities, tariff increases would be expected for better management. Andrés et al. (2008) studied the implementation of PPPs in Latin America, using data collected from 49 firms which experienced a change in ownership. In the 1980s and 1990s, a number of Latin American countries moved from a centralised management of the water industry (national monopolies) to a decentralised system where small municipal providers took charge of supplying water. Comparing tariffs before and after the transition to a privatised management, Andrés et al. (2008) found that tariffs increased substantially after the change in management, however this was attributed largely to the fact that previous tariffs were below cost-recovery levels in many cases.

Since then, the format of contracts signed under PPPs has evolved towards the management of more specific activities or objectives, such as reduction of non-revenue water, increase of energy efficiency, or the development of new sources. Smaller and less complex contracts have incentivised regional and local operators to enter the market. A number of these contracts are performance-based, that is, payments are conditional on the achievement of pre-defined specific objectives. In most cases, the day-to-day operations of the water utility are still managed by the public sector, however the utility benefits from the knowledge and expertise of private companies in specific areas.[1]

[1]Source: https://blogs.worldbank.org/ppps/5-trends-public-private-partnerships-water-supply-and-sanitation

Key messages

- PPPs cannot solve all problems faced by water utilities.
- PPPs have helped in reducing non-revenue water and improving operational efficiency, in particular by increasing labour productivity.
- Recent contracts are more often performance-based, smaller in scope, and more focused on specific objectives.
- Regional or local operators are now increasingly present in the water market.

2.6 The price of water as a tool to manage water demand

Pricing policies are usually considered better tools to manage water demand than quantity restrictions, from a welfare point of view (Roibás et al., 2007, 2019; Grafton and Ward, 2008). However, an effective pricing policy relies on the assumptions that: i) households' demand responds to price changes, and ii) households are correctly informed about the price they pay for water.

García-Valiñas and Suárez-Fernández (2022) provide a recent overview of existing knowledge regarding the driving factors of residential water demand, and the effectiveness of price versus non-price instruments as tools to manage household water use. It is now well accepted that household water demand is influenced by water price, but also that housing characteristics (presence of a garden, swimming pool etc., size and equipment of the house), weather conditions, and household demographics (in particular, household size and income), are also influential. Even if there is a widespread belief (especially among policy makers) that wealthier households use more water than poorer households, the correlation between household income and household water use is low in most cases (Nauges and Whittington, 2017), and income elasticity is often in the range 0.1–0.2. More recently, the role of values and personal attitudes towards the environment have been shown also to play a role in water use behaviour and adoption of water conservation practices (see e.g. Russell and Fielding, 2010).

Price elasticity of water demand for households with piped water is usually low, in most cases in the range -0.5 to -0.3, but elasticity may also vary depending on the location, season and household income (García-Valiñas and Suárez-Fernández, 2022).[2] Water demand is thus found to respond to water price, but the reduction in water use will always be less than the corresponding increase in price (the demand of water is said to be inelastic to its price): an elasticity of 0.5 indicates that a 10% increase in water price will induce a 5% decrease in water demand.

Low sensitivity may be explained partly by the small share of water expenditure in total expenditure or income (on average less than 2%, higher for the poorest households). The complexity of the tariffs and the low frequency of billing may also explain the inelasticity of water consumption to its price. There is evidence that consumers rarely know the marginal price or the details of the price schedule. When informed, consumers are more likely to be

[2]Estimates of price elasticity of piped water demand in developing countries are of the same magnitude (Nauges & Whittington, 2010).

aware of the total amount of their bill (Brent and Ward, 2019) and hence to be sensitive to average rather than marginal price (Ito, 2014). García-Valiñas et al. (2021), surveying households from Southern Spain, found that the level of knowledge of both consumption and bill amount is rather low, and that consumers tend, on average, to overestimate their bill and to underestimate their consumption.

Wealthier households usually consume greater volumes of non-essential water (water used for watering lawns, filling swimming pools etc.) and could more easily decrease their water usage. However, water bills represent a tiny share of their total expenditure, so those households are typically not responsive to changes in water prices. Even if deemed to be superior from a welfare perspective and highly recommended by economists, pricing policies are not always favored by utility managers and policy makers. Other non-price instruments are commonly used, such as awareness and information campaigns aimed at encouraging water conservation, subsidies for the adoption of water-saving appliances, and more recently social norms comparisons. Campaigns aimed at encouraging voluntary reductions in water consumption usually have limited impacts, and their effects dissipate in the long run (Fielding et al., 2013; Wang and Chermak, 2021). Rebates or subsidies for the purchase and installation of water-efficient devices often lead to water savings (Renwick and Archibald, 1998; Grafton et al., 2011), even if the risk of a rebound effect always exists (García-Valiñas and Suárez-Fernández, 2022).

The use of social norms comparisons (i.e. indicating to the household how its consumption compares to its “neighbours” or peers) is becoming very popular among energy and water utilities around the world. These programs are usually not very costly to implement (in terms of both financial and political costs), they are more easily accepted by customers than price increases, and they have been shown to induce some short-term reductions in energy and water use of about 2–5% (Nauges and Whittington, 2019). Based on a set of conditions on average cost for the utilities and price elasticity of water demand that are representative of less developed countries and industrialised countries, Nauges and Whittington (2019) showed that the benefit to cost ratio of social norms programs does not always outperform the benefit to cost ratio of a price policy. However, a pricing policy that would lead to the same expected reduction in consumption as a social norms instrument would mostly benefit the utility, while households would bear most of the cost.

Costs of social norms information treatments are often underestimated. Since utilities usually do not have information on household size and composition, comparison of water use between neighboring households may be quite inappropriate and misleading. The information that is provided by the utility may thus lead the household to make badly informed choices. Also, the moral cost of collecting such information is often neglected, while it has been shown that some households are reluctant to be compared to others and are willing to pay to stop receiving such information (Allcott, 2011). It has also been shown that the change in water use is temporary in most cases, the effect fading out after the program stops. Hence, nudging water consumers may help address short-term water crises but will not be sufficient to solve financial difficulties induced by (structural) low water prices.

Water conservation is one recurrent policy objective in regions suffering from water stress. However, if reduced water usage can benefit the environment, it will also lead to decreased utility revenues and hence may exacerbate utilities’ financial difficulties, especially in an industry facing very high fixed costs. It is thus important for utilities to be able to adjust their water tariffs over time (Chu and Grafton, 2021).

Key messages

- Water demand responds to price changes but is commonly found to be inelastic to its price.
- The complexity of most tariff structures and the low share of water expenditure in total income explain how households are rarely informed about the price of water.
- Other non-price instruments are preferred by water utilities.
- Social norms comparisons may impose unintended costs on households and are useful only for short-term management of water scarcity situations.

2.7 Pricing and fees policy recommendations

In most industrialised countries, the principle of (full) cost recovery that should guide the setting of water prices should guarantee the viability of the water supply system, while preserving the raw water sources and the environment. In addition, for all water users to receive correct signals on the value of the resource, prices should be set efficiently and reflect the (full) marginal cost induced by users' water consumption. Opportunity costs imposed by water abstraction in a water-scarce region, and environmental costs induced by the pollution of water bodies, must be internalised by water users in order to guarantee an efficient management of the resource.

However, these principles (full cost recovery and economic efficiency) prove to be very difficult to implement in practice, for a number of reasons: i) difficulty in estimating accurately future direct and indirect costs of water abstraction and supply; ii) other objectives (water conservation, equity, affordability) that utilities aim to achieve with water tariffs, leading to complex tariff schemes and distorted price signals; iii) political pressure to keep prices low; and iv) lack of control and regulation of informal water markets supplying non-piped households.

Our main recommendations are the following:

- Including environmental and resource costs in the price of water is necessary. It is a difficult challenge for policy makers and utility managers since, in most cases, non-market valuation studies have to be performed in order to assess the true value and opportunity costs of freshwater use. However, a number of non-market valuation studies of freshwater sources have been undertaken in different places and meta-analyses may offer valuable insights to policy makers (a meta-analysis is a statistical analysis that combines results from multiple studies). For the case of groundwater, for example, Brouwer and Neverre (2020) have run a meta-analysis covering studies made in 15 countries over three decades. These authors were able to elicit households' willingness to pay for good groundwater quality, which can be used by policy makers as a proxy for the value of the groundwater resource.[3] Also, there exist global initiatives that aim to collect information on the

[3]Median willingness to pay was estimated at $369.0/hh/year for the USA, $87.7/hh/year for Europe, and $48.5/hh/year for the other countries (Brouwer and Neverre, 2020).

values of Nature and ecosystem services, such as the System of Environmental-Economic Accounting for Water (SEEA-Water) developed by the UN Statistics Division (2012) and The Economics of Ecosystems and Biodiversity (TEEB).[4]

- Water utility managers and policy makers should be taught that one instrument can only achieve one objective. These responsible parties must understand that water tariffs cannot at the same time send an accurate price signal, recover full costs, promote conservation and be equitable and affordable. Misperception about the ability of water tariffs to achieve several objectives has led to the proliferation of complex tariff schemes. These complex schemes are so difficult for users to understand that the price no longer plays the role of a signal for the value of the resource. Complex schemes such as IBTs do not guarantee affordability and do not achieve equity objectives. On the contrary, the subsidies implicitly embedded in these tariffs mostly benefit well-off households. We advocate the use of simpler tariff schemes, featuring a unique volumetric price that reflects marginal costs, combined with cash transfer payments or rebates for households in need.
- Political pressures are strong to keep water prices low but exemptions that benefit some user groups should be avoided. In particular, farmers should not benefit from reduced water prices. They should be sent the right signals on the value of the resource. For that purpose, it is necessary that irrigation is properly metered and monitored. Agricultural policies should not encourage further irrigation development and/or the use of chemical inputs. They should instead incentivise farmers to improve irrigation efficiency and adopt practices that limit the use of chemical inputs on the fields.
- Water demand is found to be inelastic to its price in most situations. Consequently, significant increases in water prices may be needed to induce significant water conservation. The low elasticity of water demand may be explained by the fact that households are rarely informed about water prices, and by the small share that water bills represent in most households' total expenditure. The use of simpler tariff schemes may improve households' knowledge about water prices. Even if water demand is inelastic to its price, non-pricing instruments such as social norms comparisons should not be seen as substitute for pricing policies. Such instruments can be used to address short-term crises, but they cannot solve the structural problem of low prices in the water sector.
- Regulation, monitoring and control must be put in place in informal markets where private vendors operate and supply non-piped households. It is not acceptable that non-piped households pay a higher price for water than piped households. Also, part of the subsidies currently allocated to piped households could be diverted to non-piped households, who are also usually the poorest households.
- A number of developing economies face a structural problem of low prices combined with low quality of service (problems of low pressure, service interruptions and bad water taste are commonly reported). If prices have to be kept low to avoid major demonstrations and more unpaid bills, governments have to compensate for the deficit in revenues by providing subsidies to the utility. However, this may not be sufficient to help maintain the infrastructure in a reasonable condition. Then, if the quality of the infrastructure deteriorates further, it will be even more difficult for the population to accept price increases. This vicious circle, or poverty trap, is the worst-case scenario.

[4] https://teebweb.org/

3 Water markets

Markets are where buyers and sellers come together to trade goods and services and where payment is accepted by an agreed medium of exchange. The trade location can be physical or virtual. The terms "water market" and "water trade", or "water trading arrangements", are often used interchangeably, however water trade can exist between two people, whereas a water market requires several participants. A market where buyers and sellers are trading water can exist in an informal setting, or a formal setting. Water markets represent a property rights demand management approach to help share water because an alternative to having government or other authorities decide where to allocate water, after high priority needs are met, is to use market mechanisms to allocate physical volumes of water. Buyers and sellers, through trade transactions, determine where water is allocated (Grafton et al., 2022).

Water markets are increasingly suggested as a way forward to help allocate scarce water resources, and water trade represents an area of growing academic study (e.g. Briscoe et al., 1998; Easter et al., 1998; Easter and Huang, 2014; Howe et al., 1986; Maestu, 2013; Wheeler, 2021). Economists, in particular, believe in the power of markets to reallocate resources effectively and efficiently at the margin of use, and many argue that water trading is currently underutilised as a strategic tool. We discuss here the benefits, and the disadvantages, of both informal and formal markets.

3.1 Informal water markets

Informal water markets exist in many places around the world, in both urban and rural settings. Indeed, historically, informal arrangements to 'share' water between rural neighbors or users in particular locations have been in place for many years prior to the establishment of formal water markets (Maestu, 2013; Wheeler, 2021). Transactions within such informal water markets are, typically, small, not recorded, temporary (Bjornlund and McKay, 2000; Wheeler, 2021), and more likely to occur in times of water scarcity. Other informal markets operate as defacto water markets, such as the example of the Jati Lahur Basin in Indonesia where rice farmers upstream are paid by downstream bottling enterprises to leave part of their water use rights in the river (Keulertz and Riddell, 2022).

Access to adequate water services is an issue in cities of all sizes throughout Africa, the Indian subcontinent and Asia, due to rapid increases in city populations and migration issues. Consequently, local water utilities face difficulties in meeting local demand, and people must seek water through whatever informal means are available. Hence, within urban cities in developing countries, informal water markets are especially a feature (e.g. Ahlers et al., 2014; Cain, 2018; Raina et al., 2019; Venkatachalam, 2015; Vij et al., 2019; Zuin et al., 2014). Highly diverse (for profit and philanthropic) service providers, using a variety of service models, deliver water services. Water is provided in various quantities, qualities, prices and forms (e.g. sachets, bottles, barrels, tankers) in regions that do not have established water service providers. Such informal markets are usually competitive (though this can vary considerably), and all reflect a variety of differing community characteristics. Generally, no legislative and regulatory oversight exists (Grafton et al., 2022). In some areas, competition exists between established water service providers and water market vendors. For example, private vendors may offer high-quality water not provided by the network service provider (Garrick et al., 2019; OECD, 2021; Raina et al., 2019; Venkatachalam, 2015). In other areas, private vendors may offer services that are effectively an extension of the network. Garrick et al. (2019) argued that informal markets have arisen because existing water service providers have failed to fully deliver safe water at an affordable price to all, and they outline numerous case studies that suggest informal water markets can add significant value to water consumers. However, informal water markets are not without their challenges.

Key messages

- Informal water markets exist in many places around the world and are much more common than formal water markets.
- Informal water markets have very little regulation and few governance structures, although generally they only exist as they are providing some value to consumers.

3.2 Formal water markets

Most formal water markets have evolved from informal water trade arrangements within a region. When scarcity is intermittent or not that serious, or where there is a lack of water service providers, two parties may agree on informal arrangements to trade water. As scarcity becomes more prevalent or regular, water trading may become more common among several parties, leading to increased calls for formalised and standardised rules and regulations. The establishment of formal water markets involves official government legislation and sanctioned rules, processes and catchment areas. As Griffin (2006) commented, the establishment of the conditions that enable efficient trading and the eventual full emergence of markets seems to be at times more often accidental than planned.

Formal water markets are found in both rural and urban settings, though trading arrangements are most predominant in rural settings. As emphasised in Keulertz and Allan (2017), given that agriculture accounts for the majority of water consumption, it is unsurprising that most of the rural market settings are with farmers. Markets exist for both groundwater and surface water sources, mainly trading volumes of water, and water markets represent a form of a renewable natural market. Markets also exist for water quality trading (e.g. salinity and nutrient pollution trading), though they are less common that volume markets (a case study is provided later in this chapter). Hence, most of our discussion is concentrated upon water volume trading arrangements. Water markets face particular and considerable challenges, as discussed later, but characteristics of renewable natural markets include potential issues with an incomplete assignment of property rights, pervasive externalities and limited scientific information (Barbier, 2019; Hanemann, 2006).

The pathway for the development of water markets within an area and country reflects the property rights associated with water ownership and the legal, cultural and social history of a region, and any institutional barriers to change. In all formal water markets, trading of physical volumes of water involves the exchange of water rights, permanent and/or temporary, in a market framework between willing sellers and buyers. Water is traded through brokers/intermediaries or via formal exchanges. Water prices can fluctuate daily, depending on available supply and demand factors, hence it helps to ensure that the opportunity cost of water use is explicitly accounted for by users. While the needs of irrigators and agriculture play a major role in the development and use of water markets in many countries, markets have been used by both urban and environmental users. For example, expanding cities may need new water sources to meet growing demand, and water trade has been used to buy back water rights for environmental and cultural purposes (Grafton et al., 2022; Wheeler, 2021).

Established and extensive formal water markets exist in only a few countries, and the majority of these are high income countries. These include Spain, Chile, the United States, China and Australia (Griffin, 2006; Schwabe et al., 2020; Wheeler, 2021).

There has been extensive study within the economic literature highlighting the possible efficiency gains from water trade (e.g. Easter et al., 1998; Freebairn, 2005; Grafton et al., 2016; Young, 2019). As outlined by Howe (2000), water markets have the following advantages over other allocation schemes, namely:

- flexible reallocation over time in response to economic, demographic and social-value changes;
- involve only willing sellers and buyers, therefore provides security of tenure of property rights; and
- elucidate the real opportunity cost of water.

Appendix A (Table A.2) provides an overview of topics that have been studied in the water market literature. Broadly, these water market topics include: institutional conditions and frameworks; privatisation and marketisation issues; policy evaluation; farmers' willingness to pay; transaction costs; price and volume drivers; water use efficiency; environmental impacts; cultural issues; water quality; uncertainty; risk; theft and informal trade (Wheeler and Xu, 2021).

Key messages

- Formal water markets have often evolved from informal water markets, and they represent a renewable natural market.
- Formal water markets are found in both rural and urban settings, but are more prevalent in rural settings. They exist for both surface water and groundwater markets, for quantity (e.g. volumes traded) and quality (e.g. water salinity and nutrient pollution).
- Markets allow for flexible reallocation, represent voluntary trade, and help elucidate the real opportunity cost of water.

3.2.1 Types of formal water trading arrangements and trade benefits and costs

Formal water trading involves the buying and selling of water in two main forms: i) short-term or temporary transfers of water (known as water allocation or temporary trade, possibly including water leases, carry-over, parking, forwards and options); and ii) permanent transfers of water entitlements (where entitlements are also known as permanent water, shares, licenses, or rights in various countries, and can also include water delivery shares). Table 3.1 provides an overview of some of the key definitions in water markets and trading arrangements.

The ability to engage in temporary and permanent voluntary trade (in all the differing forms of trading arrangements that exist) leads to three distinct forms of economic efficiency: 1) *allocative efficiency:* where temporary trade allows short-term changes in allocative water decisions in response to changing seasonal conditions (e.g. weather, commodity price adjustments, cropping choices); 2) *dynamic efficiency*: where permanent trade allows changes in long-term farm and resource structure decisions to reflect new investment opportunities, water regulation changes or personal strategic choices; and 3) *productive efficiency*: where both temporary and permanent water price changes offer incentives for the efficient use of water resources as either an investment or input for productive outcomes (Wheeler, 2022).

Well-designed marketplace rules and infrastructure will encourage water trade participation, reduce strategic gaming, and improve efficient and equitable allocation. As outlined in the three forms of efficiency above, markets allow people to adapt to changing circumstances. As such, a substantial number of theoretical and empirical models have demonstrated the major economic and financial benefits that are possible from water trading arrangements. The economics literature has modelled welfare gain and various benefits to society from water markets, using approaches such as: computable general equilibrium models; partial equilibrium models; hydro-economic models; water demand optimisation models; theoretical approaches; and applied econometric models (e.g. Brennan, 2006; Chong and Sunding, 2006; Howitt, 1994; Shatanawi et al., 1995; Wittwer and Young, 2020; van Heerden et al., 2008; Vasquez, 2008; Wheeler et al., 2010; Zilberman and Schoengold, 2005). A large body of literature has also used qualitative methodologies to evaluate water market benefits (Wheeler and Xu, 2021). Compared to scenarios with no water trading arrangements, water trade is usually shown to improve social welfare. Our case studies in Section 3.3 provide more detail.

At the same time that economists and others espouse the benefits of water trade, there are critics of water markets (e.g. Bakker, 2007; Dellapenna, 2000; Hamilton and Kells, 2021), many of whom take a "water is too different to sell" stance (Griffin et al., 2013, p. 2). Concerns centre around ideas that water as a basic need is too unique and important to trade (and consequently water markets are immoral) (Bakker, 2007), that trade disadvantages rural communities (especially smaller farms), and that water markets create an environment for unethical behaviour and the development of water barons (Hamilton and Kells, 2021). Some governments, especially in Islamic countries, have the belief that water is a gift from God and cannot be bought or sold (though this argument can apply to many other assets as well) (Kuelertz and Riddell (2022). Wheeler (2022) reviews four broad myths associated with water markets in Australia and dismisses most criticisms. A broad summary (with some comment to wider issues surrounding markets around the world) includes:

Table 3.1 Glossary of key water market terms

Term	Explanation
Carry-over	Arrangements which allow water owners to hold water in storages (water allocations not taken in a water accounting period) for use in subsequent years.
Counterparty risk	The risk that a counterparty defaults on a contractual agreement.
Delivery share	The legal, and tradeable, right to have water delivered within an irrigation system, region or trust run by an irrigation infrastructure operator.
Financial investors	Financial investors are individuals or businesses without land ownership who generate their income through trading or leasing water to other parties. Although most financial investors own large portfolios of water entitlements, some generate their income purely through water trading without owning entitlements.
Inter-valley trade restriction	The maximum amount of water transferrable between two catchments, either due to hydrological or legal considerations.
Parking	A contractual arrangement permitting a buyer to store their water allocation on the seller's carry-over, usually from one water accounting period to the next.
Tagged Trading	Water entitlement holders can establish a "tag", changing the extraction location of allocations associated with an entitlement to a different region/zone than the zone of the entitlement (system of origin). Water extracted under a tag can only be used, not sold, and gets delivered through a "tagged trade". This delivery can be exempt from inter-valley trade restrictions.
Unbundling	The legal separation of land rights and rights to access water, have water delivered, use water on land or operate water infrastructure, all of which can be traded separately.
Unregulated river system	Rivers without major storages or rivers where the storages do not release water downstream.
Water allocation	Also called temporary water, the seasonal allocation received by a given water entitlement.
Water allocation price	The market price of a given good/commodity on the day. This is also referred to as the spot price.
Water entitlements, shares, licenses, or rights	Also called permanent water, a right to extract water from a watercourse/body every year, subject to climatic conditions. Some water entitlements provide access to carry-over.
Water forward	A contractual arrangement whereby the seller guarantees to deliver a defined volume of allocation, for a predetermined price, at a predetermined point in time in the future to the buyer. The buyer guarantees to honour the contract.
Water lease	A contractual arrangement whereby the lease taker (lessee) receives all allocation attributed to a leased water entitlement. The entitlement remains property of the lease giver (lessor).
Water option	A contractual arrangement whereby the buyer has the option, but not obligation, to deliver/have delivered a defined volume of allocation, for a predetermined price at a predetermined point in time in the future to/by the seller.

Source: Adapted from Seidl et al. (2020)

- *Myth 1: Assigning water rights to private irrigators is immoral because everyone has a right to water:* Confuses the differing uses of water and usually mistakes markets with privatisation issues. Water is not a traditional public good, many uses of water are private, and people can be excluded. The argument that creating water trade arrangements conflicts with other approaches, such as "river rights" or law enforcement approaches, is a fallacy – both can (and should) exist together.
- *Myth 2: Water trade fails to account for community, environmental or other social values, hence is detrimental for society:* Critics usually fail to distinguish between governance issues and water trade operation. Also, there is generally no recognition of the issues of original property rights allocation (which is not a market outcome – but a political/social one). Markets, and especially markets in developed countries such as Australia, can be designed to account for greater social, environmental and cultural values, and where there are serious social welfare issues usually there are many better ways to address these, whilst maintaining markets. However, it is difficult for other countries around the world that do not have the regulatory and governance institutions required for successful markets to be able always to incorporate such considerations in markets. Indeed, the evidence in Australia regarding water trading causing environmental degradation is mixed – both positive and negative externalities exist. Many so-called environmental impacts from water trading in Australia are actually associated with other factors.
- *Myth 3: Water trade decreases farm profitability and creates other negative farm and community impacts, disproportionately impacting smaller farms*: There is a lack of evidence linking water trade with farm exit, lower farm profitability, and worsening farmer mental health. Studies consistently find seasonal factors, climate and water availability, commodity prices and locational factors as the main influences on profitability. Although financial hardship is usually the main reason why irrigators sell permanent water, it is not the sole reason, and it does not necessarily become a causal factor for poorer future profitability. In addition, financial stress is the main reason for farmer psychological distress, and this occurs separate to water trade. Most arguments of small farmer disadvantage are common to all agricultural markets.
- *Myth 4: Water trade has allowed the participation of non-traditional stakeholders and consequently increased negative collusion and cartel behaviour*: Empirical evidence in Australia consistently finds that water market movements are predominantly driven by seasonal conditions, with little evidence of collusion and cartel behaviour. However, for markets in countries that either a) have a small volume of trades, and/or b) have very concentrated/powerful buyers (or sellers), coupled with a lack of overall governance in general, then market power issues may be prevalent.

However, although much discussion about actual water market operation is ill-informed and incorrect, this does not mean that water markets represent a panacea for water management. Although it was at the International Conference on Water and the Environment in Dublin in 1992 where the fourth guiding principles for managing freshwater resources was: that water has an economic value in all its competing uses and should be recognised as an economic good (Keulertz and Riddell, 2022). Although some proponents have taken this principle to the extreme and believe that water can be treated (and traded) just like every other commodity. We agree with Griffin et al. (2013) that the "water is no different from other commodities" argument places too much faith in the ability of the market system to create an efficient economy. Water markets, like other markets in society, need to be scrutinised for imperfect competition, externalities and information asymmetry. They are not immune to these problems (Wheeler, 2022). There may also be serious distributional issues and pecuniary externalities needing consideration. In trying to establish water markets as a natural resource renewable market, consideration must be given to their significant water meta-governance requirements (e.g. Bell and Quiggin, 2008; Freebairn, 2005; Grafton et al., 2011, 2016; Young, 2019).

It is critical to note that water trade only exists within institutions, hydrological rules and structures, which allow and govern the transfer and use of water. Hence, meta-governance frameworks and the sequencing of any water reform is crucial. If the meta-governance needs (e.g. institutions, knowledge, regulations and structures) that oversee water trade, extraction and management, are corrupted, or are missing or incomplete, then this can result in negative impacts for society (Wheeler et al., 2017). Even the most developed and adopted water market in the world, in the Murray-Darling Basin of Australia, has shown a need for meta-governance improvement, in terms of: monitoring and compliance; measurement of water extraction; developing national independent water body institutions; water pricing; and water accounting (Wheeler and Garrick, 2019). The following section provides greater detail about the conditions associated with greater water market development.

Key messages

- There are two main types of formal water markets: temporary (trading a seasonal right to water); and permanent (trading a long-term right to water).
- Water trade leads to three types of efficiency: allocative, dynamic and productive, with much empirical evidence suggesting significant net benefits.
- Despite the demonstrated benefits, many myths surround water markets, which are often not founded in evidence.

3.2.2 Necessary conditions for formal water market development

Experienced commentators know that although water trade arrangements can bring many benefits, at the same time markets are far from a panacea for all water reallocation problems, and indeed are highly complex economic instruments to design, develop, implement and sustain over time. Numerous authors have discussed necessary conditions needed for formal water markets. They include: Matthews (2004), who highlighted questions relevant for the establishment or reform of a water rights system; Young (2014) and OECD (2015), with descriptions and checklists of key water institutional design principles; Grafton et al. (2011), providing comparison of water markets across countries; Perry (2013), listing requirements for effective water resource management; Keulertz and Riddell (2022) providing the various accounting factors needed for water markets and Möller-Gulland and Donoso (2016), listing ten criteria which influenced the emergence or creation and success of water market intermediaries.

In these assessments, any issues regarding trading arrangements are usually the last in the checklist, emphasising the need for major transformational reform before making further transitions to water trading arrangements. Wheeler et al. (2017) sought to build on previous work by providing a common non-prescriptive framework to evaluate the appropriateness of water allocation arrangements to facilitate low-cost trading.

As such, the water market readiness assessment (WMRA) framework was developed, which consisted of three steps in the process to establish water markets:

1. *Step One: Enabling Institutions*: this included defining the total resource pool available for consumptive use and hydrological factors of use; and evaluating the current institutional, legislative, planning and regulatory capacity to facilitate water trade, involving: i) specifying each resource share in perpetuity while allowing for changes in the proportion allocated to each share (comprises setting caps on water extraction across areas and sources and setting regulations on use); ii) fully assigning responsibility for managing supply risk to users; iii) ensuring enforcement, strict regulation of caps and monitoring/compliance; and iv) keeping transaction costs low.
2. *Step Two: Facilitating Gains from Trade*: developing clear and consistent trading rules; assessing benefits and costs of market-based reallocation, for example, numbers of individuals who can trade (versus adoption of trade); and homogeneity of water-use, adaptation benefits, cost of water reform, ongoing trade transaction costs and assessment of externalities. There is a difference between legislating for water trade to occur, allowing transfers between a small number of individuals (or allowing aggregation of small amounts of parcels to allow a trade versus broader water reform legislation (e.g. creating water registers with transparent, complete and fully accessible data, clearer trade rules and public information sources).
3. *Step Three: Monitoring and Enforcement*: use of water markets and water extractions needs ongoing monitoring and enforcement to ensure compliance, as well as continued development of trade enabling mechanisms, including: seeking to limit/reduce transaction costs; scanning for unanticipated externalities; developing new market products (e.g. option contracts or forwards); and then implementing, if needed, new legislative changes and planning requirements. Water market rules need flexibility to ensure water security and manage future uncertainty.

Steps one and three, above, outline water governance principles that are desirable for any property rights regime, while step two lists specific institutional factors required for water markets.

Appendix A (Table A.3) provides further detail on the various factors that help enable the development of formal water markets and on basic institutional governance that is needed. Wheeler (2021) applied the water market framework above in a wider range of contextual applications across as many different countries as possible. In total, various chapters in that book assessed 28 regions, 20 countries and six continents, for the extent of institutional water governance development and formal water market adoption. Key conclusions were that only one case study country in Africa and Asia – China – had gone past the basic step one of establishing property rights and strong independent water institutions. For case studies in Europe, America and Oceania, only six regions had reached the final step three of the water market framework. There was also significant diversity in development within a country.

Key messages

- Although water markets can have many net social benefits, they are not a panacea and require complex governance and institutional frameworks to oversee and regulate.
- Markets can develop in stages, with governance frameworks needed at each level.
- Given the complexity of water markets, there remains only a handful of countries around the world that have reached the level of significant adoption.

3.3 Case studies of water markets around the world

This section provides five case studies of water markets around the world. These are: Africa; Australia; Chile, People's Republic of China and the United States.

3.3.1 Africa

Matchaya et al. (2019) highlight how the emergence of water markets in southern Africa has been influenced by the continued depletion of water resources – resulting in the adoption of innovative water trading strategies, such as joint farm venture systems along with intra-basin and inter-basin water transfers. The absence of water markets in Africa was typically due to the underpricing of water, as it was regarded as a social good rather than an economic good. For example, during the 1980s, South Africa used to price water at 30% of the operation and maintenance costs (Tewari, 2017). Tewari (2005) provides an overview of the development of water policy in South Africa. As a broad summary, water policy followed the country changing hands from the Dutch, to the British, to the Afrikaners to a Government of National Unity. In terms of who owns the water rights, climatic conditions, hydrology, location and water uses are among the important factors in the evolution of water rights in South Africa. The riparian and appropriation doctrines were important. Under the riparian doctrine, the right to use water resides in the ownership of riparian lands adjoining the water body. Under the appropriation doctrine, the right to use water requires (1) a diversion from the water body on a first-in-time, first-in-right basis, (2) subsequent continuous use, and (3) beneficial use. A third corrective rights doctrine (i.e. the current phase) is to combine certain elements of these two doctrines, where the aim is to facilitate water access for previously disadvantaged communities, but also to promote development and sustainability. Among other factors, sociocultural contexts are also important determinants of water rights. In 1998, when the *South African Water Act* was passed, where only basic human needs and environmental sustainability were guaranteed as a right, the rights of irrigators were of secondary importance. South African water licenses are not to exceed 40 years, they must be renewed within five years of when the license is issued, and the water must be used beneficially (Tewari, 2017). Water markets emerged from late 1994 onwards in the Lower Orange River area, which was developed with a centralised nonmarket water allocation system controlled by the government and was dependent upon land characteristics. Studies suggested that water transferred to higher value uses (Nieuwoudt and Armitage, 2004).

Limitations and risks of long-term intra-basin and inter-basin water transfers from the countryside to cities are that they may increase conversion of rural areas into urban areas and cause ecological problems. This also might exacerbate inequality between the water poor and the water rich households or regions (Matchaya et al., 2019).

However, water markets are rapidly growing, stimulating water pricing from an opportunity cost perspective through the interaction between demand and supply forces. Matchaya et al. (2019) conclude that while water markets are relatively new in southern Africa, they represent huge potential for harnessing the best use of very limited water supplies and expanding opportunities to improve water productivity and water use efficiency. Effective water markets, however, are only possible where functional institutions and legal frameworks are in place (Wheeler, 2021). In southern Africa, water markets are typically governed by more informal water-related frameworks. Tewari (2017) argues that proper water rights and administration systems need first to be securely put in place, in South Africa, and that it is necessary for considerable changes to how private ownership of water in the public domain is viewed and for a reduction in the high transaction costs.

Nonetheless, successful water markets have benefited some regional communities, as proceeds from water transfers have been channelled back to improve local infrastructure and livelihoods. Due to the highly uneven distribution of water resources across southern Africa, their transboundary nature and the shared challenges experienced by many countries – together with regional targets of integration and poverty reduction – water markets can contribute towards achieving regional goals and improving the livelihoods of people (Matchaya et al., 2019).

3.3.2 Australia

The Murray-Darling Basin (MDB) in Australia provides a leading example of the benefits to be derived from implementing water markets. The MDB covers all or part of five states/territories in Australia and produces over one third of Australia's food supply. Agricultural access to water has been subject to considerable variation in the MDB, with droughts occurring regularly.

English riparian doctrine and common laws were adopted in Australia's colonial settlement in 1778. Federation of Australia occurred in 1901, and water was one of the arenas for which states fought for sovereignty, with continued dialogue about how to share water between states. Indeed, severe drought first lead to informal water "swapping" in the 1940s. Some states stopped issuing new water licenses (e.g. they "capped" existing water licenses) from the late 1960s onwards, with informal and early MDB markets for temporary water starting in the 1960s and 1970s. Leases (temporary trade) were trialled officially in the early 1980s, and trade between private diverters and district irrigators started from 1995. The unbundling of land and water rights followed, with further institutional and policy reforms in the 2000s (Wheeler, 2014).

Unbundling initially separated land and water. A further development was to unbundle the water license into i) an access right to receive seasonal allocations; ii) a volumetric seasonal allocation credited to an allocation account; iii) a water use right which allows the holder to extract the allocation and put it to a defined use; and iv) a delivery capacity right which allows for the delivery of allocations. Except for the water use right, all licenses can be traded separately. To irrigate, a farmer needs the last three rights, but does not need access rights because temporary water can be credited to an account, either in the form of yield from a water access right held by the account holder or by purchase. Hence, it is now possible to sell a license without terminating delivery capacity rights, use right and/or the allocation account (ACCC, 2010).

There are both regulated and unregulated water licenses in Australia. Regulated water has different levels of reliability (namely high, general and low security) by area. Unregulated systems have no formal reliability, and they are usually determined by restrictions on extraction. To date, most water trade has been in regulated water leases in the MDB. Historically, many high security licenses have received in excess of 100% water allocations, although from the 2000s onwards this has been more variable.

Unlike other areas in Australia, most parts of the southern MDB are hydrologically linked, which allows water trade to occur over a large distance (and has the highest trades – see Table 3.2). The water allocation market was adopted far earlier by farmers than the water entitlement market, with trade rising exponentially over time. Although there has been limited trade in groundwater, unregulated leases, options, forward contracts, or in non-MDB systems, trade in other areas of Australia is growing, and water brokers are regularly introducing new water market products. Northern MDB water markets are much less developed, which Wheeler and Garrick (2020) attributed to relative illiquidity, lower storage, less hydrological connectivity and crop diversity, less regulated water rights, more homogenous agricultural production, far greater on-farm water storage and groundwater extraction. Table 3.2 shows the volume of allocation trades in Australia during 2020–21, which has grown substantially over the last decade (BoM, 2022). A record volume of allocations was traded in 2020–21, increasing by 27% from the previous year, although the number of transactions was similar.

Table 3.2 Water allocation trade summary in Australia 2020-21

Region	Resource Type	Transactions	Trades with market rate price reported[1] (%)	Volume (GL)	Estimated Turnover[2] (AUD M)
Southern MDB	Surface Water	29,890	57	7,267	469
Northern MDB	Surface Water	1,035	34	350	30
Groundwater MDB	Groundwater	718	53	172	17
Rest of Australia	Surface Water	2,023	9	186	3
	Groundwater	286	19	16	1
Australia – Total	Surface and Groundwater	33,952	53	7,991	520

[1]Allocation trade market rate price involved transactions with a reported price above $5/ML and below $10,000/ML
[2]Price data have been cleansed to remove zero prices and outliers that are unlikely to be valid (see BoM, 2022 for details)

Source: BoM, 2022

Regarding volumes of water entitlements traded, 2,547 gigalitres (GL) were traded nationally in 2020/21, a 30% increase compared to the previous year (Table 3.3). Once again, this record high volume of entitlement trades was primarily driven by increased trade in the southern MDB (BoM, 2022).

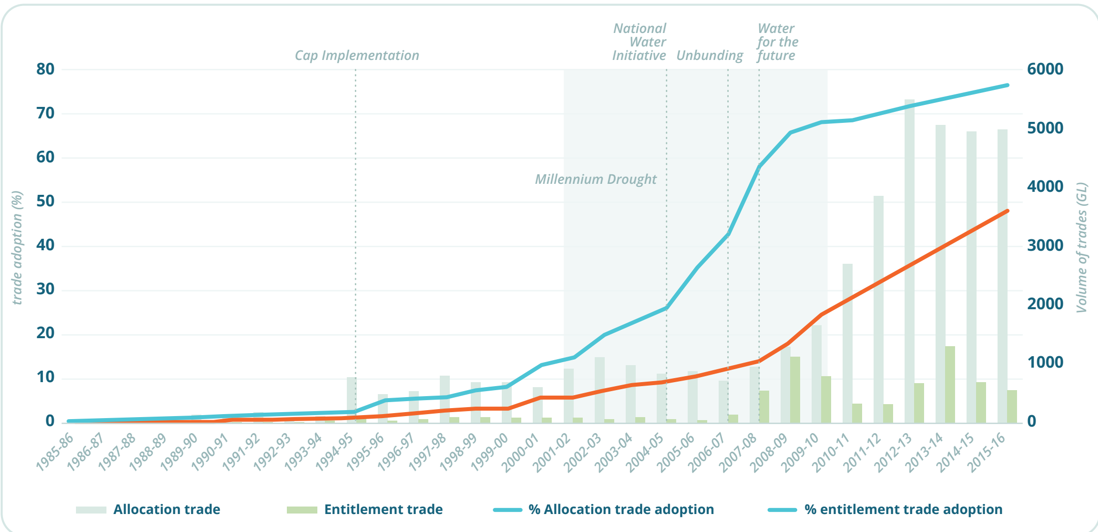
Table 3.3 Water entitlement trade summary in Australia 2020–21

Region	Resource Type	Transactions	Trades with market rate price reported[1] (%)	Volume (GL)	Estimated Turnover[2] (AUD M)
Southern MDB	Surface Water	3,836	51	1,662	3,930
Northern MDB	Surface Water	448	41	174	450
Groundwater MDB	Groundwater	827	36	170	260
Rest of Australia	Surface Water	2,867	22	316	670
	Groundwater	1,619	10	225	290
Australia – Total	Surface and Groundwater	9,597	34	2,547	5,600

[1]Entitlement trade market rate price involved transactions with a reported price above AUD 50/ML and below AUD 20,000/ML
[2]Price data have been cleansed to remove zero prices and outliers that are unlikely to be valid (see BoM, 2022 for details)
Source: BoM (2022)

In terms of monetary value of water traded, water markets in Australia had an estimated turnover of AUD $6 billion (see Tables 3.2 and 3.3), down from a record high of AUD $7 billion in 2019–20. With increased rainfall leading to improved water availability in 2020/21, there were record high volumes of water allocations traded (7,991 GL) and therefore prices paid decreased significantly from the previous year (BoM, 2022). Figure 3.1 provides an overview of time taken for water markets to be adopted as a form of water management.

Figure 3.1 Adoption of temporary and permanent water trade in the southern MDB



Sources: Adapted from Grafton and Wheeler (2018) and Wheeler and Garrick (2020)

In the last couple of decades, water markets in Australia have been used as a vehicle to facilitate the largest reallocation of water from consumptive to environmental use in the world. The Millennium drought in the 2000s led to major water reforms: the Commonwealth Water Act 2007; the National Plan for Water Security in early 2007 (which became Water for the Future in 2008); new administrative bodies such as the Murray-Darling Basin Authority (MDBA); the Commonwealth Environmental Water Holder (now the Commonwealth Environmental Water Office, which was created to manage acquired consumptive water and thereby increase environmental flows); and, the legislation of the Murray-Darling Basin Plan in 2012 (Wheeler, 2014).

The plan legislated a target for environmental water recovery volumes for 2,750 GL (around a 20% decrease in consumptive use across the Murray-Darling Basin). Initial investment for this recovery was AUD $12.9 billion investment over 10 years to 2018–19, with significant emphasis placed on the role of water markets to voluntarily recover water for the environment (through voluntary buybacks of water entitlements from irrigators). Other environmental water was to be obtained through infrastructure investment (both on and off-farm), which was given double the budget of buybacks (Wheeler, 2014). Despite the disparity in the budget, most of the Commonwealth water has been sourced through a program buying water directly back from irrigators, while just over a third has been sourced through infrastructure expenditure (Grafton and Wheeler, 2018). Buying water back from irrigators has had less popular support than subsidising irrigation infrastructure – mainly because of myths surrounding economic impact and water markets (see Wheeler, 2022 for further comment), but also because of the money involved in both programs. In short, as at early 2019, water recovered cost AUD $2,019/ML through the buyback program, and water recovered via irrigation infrastructure cost AUD $5,453/ML (2.7 times more) (Wheeler et al., 2022). Many issues and problems are also found to be associated with subsidising irrigation infrastructure as a form of water recovery – see Wheeler et al. (2020) and Grafton et al. (2018) for a summary.

3.3.3 Chile

Chile was an early adopter of water markets. The Chilean Water Code of 1981 allowed for water rights to be transferable in order to facilitate the use of water markets to reallocate water. Chile has a long tradition and culture, dating back to colonial times, of managing water resources with water rights. Water markets are driven by demand from relatively high-valued water uses and facilitated by water scarcity and low transactions costs in valleys with flexible water distribution infrastructure, and where water user associations exist. In the absence of these conditions, trading has been rare, hence trading is not a common form of adaptation (Donoso et al., 2021).

Many transactions have been for relatively small amounts of water and for low transactions amounts, with most transactions between agricultural users. In general, intersectoral water transfers are infrequent. Even in active markets of the Limarí basin, only 2% of transactions between 2000 and 2016 transferred water out of agriculture (Hearne, 2018). Prices have been highly variable. This large price dispersion is due to the lack of reliable public information on prices and transactions, with each transaction the result of a bilateral negotiation between an interested buyer and seller (Donoso et al., 2021). The market for non-consumptive water rights has traded approximately 2.6 million L/s between 2009 and 2014 (Cristi et al., 2014). In terms of market activity measured as the percentage of the total volume of granted non-consumptive water rights, about 20% have been traded (Cristi et al., 2014). In a review of national water market trends, Cristi (2011) reviewed the database of transactions in the registry of water-use rights that is maintained by the Chilean General Directorate of Water (see Table 3.4).

The figures are for water market transactions independent of land transactions, for the years 2005–2008 (Hearne and Donoso, 2014). These transactions cover the entire country and are not limited to the most frequently studied regions of the Limarí Basin (IV Region) and the Maipo and Mapocho Basins (in the Metropolitan Region). Approximately 88% of these transactions were for consumptive use rights (Cristi, 2011). Although water markets are most active in central Chile from the Coquimbo to the Maule regions, transactions occur throughout the nation.

Table 3.4 Water market transactions in the Chilean national water-use rights registry

	2005	2006	2007	2008	Total
Number of water market transactions					
Arica y Parinacota and Tarapacá	92	179	197	96	564
Antofagasta	13	7	63	48	131
Atacama	4	10	1		15
Coquimbo	775	1,231	1,155	287	3,448
Valparaiso	513	732	926	668	2,839
Metropolitan	585	1261	1210	1170	4,226
O'Higgins	465	568	513	464	2,010
Maule	968	1,471	1,678	2,042	6,159
Bío-Bío	300	643	934	285	2,162
Araucanía	145	200	29	113	487
Los Ríos and Los Lagos	28	131	39	25	223
Aysén	0	11	47	10	68
Magallanes	0	4	2	0	6
Total	**3,886**	**6,448**	**6,794**	**5.208**	**22,338**

Source: Cristi (2011), Banco Central de Chile. These data precede the 2006 changes to Chile's regions. Therefore, Arica and Parinacota remains combined with Tarapacá, and Los Ríos and Los Lagos remain combined.

3.3.4 People's Republic of China

Water rights in the People's Republic of China are owned by the state and have the mixed nature of public and private rights. Water rights trading in China involve a) user-level: trading of temporary rights between irrigators; b) group-level: trading of long-term rights between industry and agriculture; c) regional level: trading of either long-term or short-term rights between governments; and d) water banks and inter-basin trading. Svensson et al. (2021) reported that trading accounted for 0.2% of total water consumption in China in 2019, but that water markets had spread over more than thirty cities in the last two decades. Group-level trading was the most common, followed by regional level trading, and then user-level trading. Svensson et al. (2019) discuss the evolution of water markets in Heihe, Shizyang and Yellow Rivers in China. They suggest that path dependence matters, and the development of hard water infrastructure and consequent scarcity and sinking groundwater tables in down-stream areas, meant more focus was given to soft infrastructure rules and market development, especially from 1998 onwards.

Xu et al. (2021) assert that while China is committed to building a water-saving society, including measures to establish a water market, after a decade of development China's water market remains inactive. China requires ever-increasing amounts of water for industrial and agricultural development; however, water resources are inadequate and unevenly distributed (Di et al., 2020), exasperated further by low per capita occupancy rates and severe water pollution problems. In addition, some regions of China are experiencing further water shortages due to changing rainfall patterns in recent years.

In the absence of a national water market framework, the relevant departments have built three levels of water rights trading platforms, these being the national level, provincial level, and below-provincial level (see Table 3.5).

The China Water Exchange (CWE) is a national water rights trading platform intended to promote the marketisation of water rights trading and to improve the efficiency of allocated water resources. The provincial trading platforms have established strategic partnerships with the CWE, so that transactions cover areas such as Hebei, Inner Mongolia, Ningxia and so on. Furthermore, there are at least ten trading platforms at the provincial level – of which the Shiyang River Basin Water Rights Trading Centre is one of the larger representatives (Xu et al., 2021).

In conclusion, Xu et al. (2021) found that information asymmetry in China's current water trading mechanisms leads to a final transaction price far higher than the benchmark price. The bargaining power of both parties is very different, with the buyer at a distinct disadvantage. This scenario is not conducive to growing activity within a water rights trading market, given it seriously affects the efficient allocation of water resources and hampers the economic development of water resource-poor areas.

Jiang et al. (2020) conducted an analysis of China's water policy over the previous two decades, highlighting the interplay between two key trends in water governance: state control and marketisation. Their analysis showed that developments in water rights and water trading have progressed alongside renewed growth in water supply infrastructure and continued state control of water rights and allocation. Furthermore, the authors argued that – rather than contradicting or displacing each other – these two trends in water management

Table 3.5 Chinese water rights trading platform across different levels

Level	Counterpart trading platform	Platform function	Regulatory authority
National	China water exchange	Information publication, water rights trading intermediary business	China securities regulatory commission and ministry of water resources
Provincial	**Guangdong** – environmental water rights exchange **Henan** – water rights collection and transfer centre **Inner Mongolia** – autonomous region: water rights collection and transfer centre **Ningxia Hui** – autonomous region: water rights trading platform **Shandong** – water rights trading platform	Water rights collection, storage and transfer business, information dissemination, intermediary services, etc.	Provincial people's government and water administration department
Below Provincial	**Chengan** county – water rights trading platform **Hutubi county** – water rights trading centre **Shiyang river basin** – water rights trading centre **Shule river basin** – water rights trading platform	Water rights collection, storage and transfer business, matching transactions, optimal allocation, etc.	Local governments and water administration departments

Source: adapted from Xu et al. (2021)

are complementary, fostering a distinctive governance regime that serves broader political and economic targets, as well as the critical goal of water security.

Di et al. (2020) applied a dynamic differential game model based on water reallocation in the Yellow River basin. Under this model, the water management authorities of the basin and surrounding regions would seek to maximise their own value of available water resources. The dynamic differential game and pricing game models performed well in determining the optimal trading quantity of water in each region, the bargain price with optimal results of CNY 409.41 billion per year outperforming other methodologies.

3.3.5 United States

In the western United States, an area with a dry climate and over-allocated river systems, water is allocated primarily by historical precedent and is fixed. The first user to extract water for beneficial and reasonable purposes is granted the water right. Senior (older) rights are the first served in periods of water scarcity. Although these rights are separated from land property and are theoretically tradable in practice, regulatory doctrines such as "no injury rules" (which usually mean that rights can only be traded if they do not negatively affect downstream users), transaction time costs of trade, and legal costs, represent trade barriers (Breviglieri et al., 2018).

Water rights and terminology are not homogeneous between states, limiting the possible scale of water markets in the US. Areas where local markets have emerged include Colorado, Arizona, California and Texas (Schwabe et al., 2020). The most active and mature water market in the US is in Northern Colorado. This is an infrastructure project that diverts water through the Rocky Mountains through a series of tunnels and reservoirs, which when finished in 1957 meant that water on the eastern side could be allocated to users, with homogeneous quotas adjusted seasonally and easily tradable between users (Breviglieri et al., 2018).

In California there are two forms of water trade that are different to the norm (i) fallowing an agricultural field and trading the water that would have been used if that land had been cultivated; and (ii) reducing water use and trading the volume saved. Hence, conservation efforts are accepted as beneficial uses, facilitating transfers and the emergence of markets. In particular, two water districts in California – Palo Verde Irrigation District and Metropolitan Water District – allow irrigators to fallow land and sell water temporarily for urban use in Los Angeles and San Diego (Breviglieri et al., 2018).

Table 3.6 shows the acre-foot price of water leased or sold between 2009–18 across three US states – Arizona, California and Texas (Schwabe et al., 2020). The price associated with permanently traded water in Arizona was around USD $2,046 per Acre-Foot (AF), on average, whereas the price associated with a temporary sale registered at approximately USD $130/AF, on average; consequently, the lease price was about 6% of the sales price. This percentage was consistent for the states of California and Texas. The change in the three-year moving average over 2009–2018 indicates that the price per acre-foot traded through leases increased slightly by 1.40%.

Table 3.6 Water lease and sales price USD/acre-foot (USD/AF) by year (2009–2018) and state

	Arizona		California		Texas	
Year	Leases	Sales	Leases	Sales	Leases	Sales
2009	228	2,125	224	1,544	96	4,217
2010	125	807	197	2,498	122	3,293
2011	89	2,252	183	5,981	106	501
2012	69	3,067	224	3,692	115	3,016
2013	99	1,131	218	3,797	112	4,290
2014	121	2,032	334	9,230	186	1,903
2015	126	1,796	446	3,700	159	793
2016	162	1,294	381	4,095	164	1,354
2017	126	153	278	2,707	163	1,119
2018	159	5,809	287	5,442	167	3,023
Average	130	2,046	277	4,268	139	2,351

All prices are in real US dollars in 2009 using the CPI-All Urban Consumers Average from the US Bureau of Labor Statistics (BLS, 2022).
Source: Schwabe et al. (2020; p 5)

Other trades possible in Arizona and California included groundwater banking, and entitlement to use treated wastewater can also be traded in Arizona, California and Colorado. Entitlement to store water for use in a surface reservoir, known as "Storage Water Rights", is possible in California and Colorado.

Most of the US water market transfers are associated with temporary leases, as opposed to permanent water right trades. Overall, the amount of water traded is small relative to the total water used, between 2% and 4%. Schwabe et al. (2020) suggest that there are multiple factors across the states that contribute to inhibiting the market from achieving its full potential, including high transaction costs associated with often multiple layers of approval, a lack of transparency, poor and incomplete information flows, along with conveyance and infrastructure limitations.

3.4 Summary of formal and informal water markets

3.4.1 Drivers of water market development and adoption over time

Studies that have traced the development of various water markets over time emphasise the following key factors:

1. *Adoption is slow at first*: The initial adoption of formal water markets follows a slow pace, and often evolves from years of informal (or de facto) water trade arrangements. Farmers are more likely to adopt (or try out) short-term trading arrangements first and are slower to participate in long-term permanent water trading arrangements (Grafton and Wheeler, 2018). Some countries may never evolve from informal water markets, and this may be the most socially beneficial scenario for them.
2. *Water scarcity factors hasten adoption*: Severe water scarcity hastens adoption of water trading arrangements. Periods of drought and low water allocations increase incentives and requirements to trade water. Greater diversity of crops and agriculture also increases incentives to share water across industries, given different seasonal water needs and the ability of some annual industries (such as cotton and rice) to reduce production in a given year (Griffin, 2006; Young, 2014; OECD, 2015; Grafton et al., 2022).
3. *Institutional changes and transaction costs matter*: Improved water market platforms, information and reduced transaction costs of trade, can increase incentives to enter the water market. For example, the development of online water market trading, or the decrease in the time taken to approve permanent water market trades, can increase incentives to engage in the market (Wheeler et al., 2017).

Table 3.7 below provides a summary of the broad characteristics of formal and informal water markets.

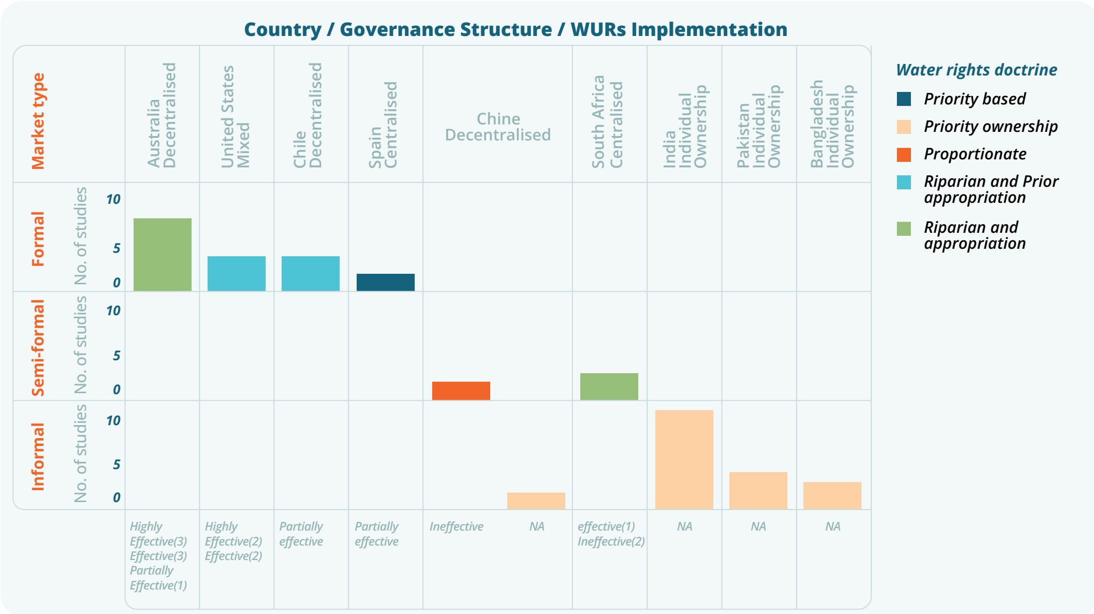
Bajaj et al. (2022) conducted a systematic literature review on formal and informal water markets around the world. Figure 3.2 provides a graphical overview. Figures 3.2 illustrates some case study overviews of informal markets in India, Nepal, Angola, Pakistan and Bangladesh.

Table 3.7 Overview of characteristics of formal and informal water markets

Type of market	Formal market				Informal market	
	Formal broad-based water market	Formal agricul-tural water market	Formal ag to urban water market	Formal urban water market	Informal ag water market	Informal urban water market
Description	Permits trading of water rights and annual allocations between entities covering all water users and investors. Where infrastructure permits, allows intersectoral trade. Requires strong legal framework and institutions, good information flows, and effective compliance. Applies to both groundwater and surface water.	A subset of a broad-based water market but limited to agricultural trade.	Similar to formal agricultural water markets, except that purchaser will be an urban water utility or user.	Market structure developed to address long held concerns with anti-competitive aspects of monopoly service provision. Operate in very few countries.	Irregular arrange-ments without regulatory oversight.	Commonly seen in rapidly growing cities in emerging countries. Water vendors provide enhanced access to clean water supplies, where public water utility hasn't met demand. Some markets involve private business while others dominated by communities.
Transaction size	Surface water trading tends to be large (tens of ML). Groundwater trading tends to be geographically confined and smaller.	As for broadly based water market.	Trades tend to be large to very large, depending on size of receiving community or user.	From small kilolitres to large ML.	Large (tens of ML).	From small containers (under a litre) to water tankers (many kilolitres), depending on community and consumer needs.
Infrastructure requirements	Headwater dam required for regulated system. Rivers, pipes, pumps and meters are key tools. Accurate info. and effective compliance are key for unregulated systems, where metering is critical.	As for broadly based water market.	As for broadly based water market.	As for broadly based water market.	Utilising existing immediate area irrigation infrast-ructure.	Require initial access to supply (e.g. may draw on public water supply or groundwater from peri-urban areas). Otherwise, vary greatly, according to market characteristics
Effects	Facilitates movement of water from low to higher value uses.	Provides better balance sheet use; improves resiliency; improves competitive-ness.	Provides urban areas with lower cost access to additional supply. Improves resiliency in face of climate change.	Increases efficiency, driving cost savings.	Improved efficiency among small number of parties.	Promotes access to clean water, providing a potential vehicle to address SDG 6 challenges.

Source: Grafton et al. (2022; pp. 14-15)

Figure 3.3 Graphical overview of selected formal and informal water markets



Source: Bajaj et al. (2022; p. 5)

3.4.2 Insights for future water market development

Following on from Wheeler (2021) and Grafton et al. (2022), key specific overall insights for future water market development and adoption from this world assessment include:

1. *Formal water markets are not for everyone – facilitating and improving informal water markets (or allowing trade between two stakeholders) may be just as important*: Given the requirements for formal water markets, not all countries will be able to develop them successfully. Informal or de facto water markets can be just as important, especially in areas that lack water governance or may be opposed to the idea of water markets in general.
2. *Initial property right distribution matters*: Who owns what water rights (either in volume or seniority of rights) is a critical factor for understanding some of the beneficiaries of water market trading. If certain stakeholders were deliberately excluded from original rights to water, for reasons of colonisation etc., then this raises serious distributional and equity issues. Formal water markets may help or hinder such distributional issues, depending on how they are implemented and operated. Distributional issues should theoretically be addressed before establishing water markets but can also be addressed afterwards (see point 6 below).
3. *Establishing sustainable (and adaptable) water extraction caps (i.e. limits)*: The importance of establishing sustainable water extraction (groundwater and surface-water) caps (limits on water extraction) is critical. Such limits to extraction is lacking in many countries around the world.
4. *Water accounting*: Many countries lack basic hydrological information. For example, sound measurement of all inflows, water consumption, recoverable return flows and flows to sinks return flows, need to be included in a water accounting framework. Water accounting can also help to identify subsidies (in either resource use or for irrigation infrastructure provision) that are present in regions that distort both decision-making and efficient water extraction.

5. *Measuring and monitoring extractions and enforcing extraction limits*: Very few countries have successful measurement and monitoring of water extraction. The continual development of satellite and thermal technology in measuring water extraction and consumption may provide one of the most cost-effective measures for countries to adopt in the future and is currently being used in a few countries.
6. *Cultural and environmental values*: Although some countries have started incorporating environmental values into water markets, few have successfully dealt with cultural values or distributional values of initial property rights, so traditional indigenous rights are ignored. The cultural values of Indigenous owners for rivers in various countries will need much greater attention going forward, in terms of initial distribution of property rights in some areas, and reallocation in other areas.

Therefore, the evolution of water markets represents a continuous journey of adaptation as circumstances change in relation to water users, institutions and the environment. While formal water markets may deliver substantial benefits to some water users, they need careful implementation and ongoing improvement. Hasty decisions to develop water markets too quickly and allowing "unfettered" water trade prior to the reconfiguration of the administrative arrangements to adequately manage water supply and demand, may be destructive to, rather than supportive of, water security (Maestu, 2013; Young, 2014). On the other hand, too much regulation and institutional capacity will also stifle the significant benefits that can be gained from water trade and hamper further adaptation to climate change.

Key messages

1. Water market (formal and informal) case studies were undertaken for Africa, Australia, Chile, China and the United States.
2. Overviews of water market development and drivers of adoption were provided, with three key lessons for water market development: 1) adoption is slow at first, and temporary markets are adopted faster than permanent markets; 2) water scarcity hastens adoption; and 3) institutional and governance frameworks matter, and high transaction costs impede trade.
3. Following the above, six key lessons for formal water market development include the need for: 1) recognising formal water markets are not suitable for all countries, sometimes informal water trade may be more beneficial; 2) understanding that initial property right distribution matters, and preferably equity issues should be addressed before establishing formal markets; 3) establishing sustainable (and adaptable) water extraction limits: 4) water accounting development; 5) measuring and monitoring extractions and enforcing extraction limits; and 6) further inclusion of cultural and environmental values.

4 Concluding comments

Given growing demand for water, coupled with ongoing climate change and the fact that cost-effective supply augmentation projects are becoming more limited globally, increasingly water demand management strategies will need to be explored and implemented. In particular, economic incentives such as water pricing and water markets will need greater development and adoption. This report has discussed the various principles associated with water pricing and costs and provided a set of recommendations to guide water pricing in various settings. Some key water pricing and cost findings included:

- A necessary principle for ensuring the viability of the water supply system is that water users should pay a price that reflects both direct and indirect costs of water consumption. This is known as the economic efficiency principle.
- Remove or avoid subsidies that promote increased water extraction or water pollution.
- Water conservation and equity objectives lead to distortion of price signals.
- Affordability should be addressed using complementary instruments, such as vouchers, cash transfers or rebates. Equity issues should not be addressed by providing water for free.

The second half of the report analysed property right approaches to water and describes in full formal and informal water markets. A series of case studies provide further detail, and this section concluded with a set of insights into further water market development. Some of these insights included:

- Markets allow for flexible reallocation, represent voluntary trade and help elucidate the real opportunity cost of water.
- Water trade leads to three types of efficiency: allocative, dynamic and productive, with much empirical evidence suggesting significant net benefits.
- Water markets are not a panacea and require complex governance and institutional frameworks to oversee and regulate.
- Initial property right distribution matters, and preferably equity issues should be addressed before establishing formal markets.
- Where formal water markets cannot be established due to governance or transaction cost issues, informal water markets or trade can be beneficial.

Finally, it needs to be recognised that demand management instruments – such as water pricing and water markets – need to be implemented as part of a portfolio approach towards water management in general. They will work best in combination with other water management tools (e.g. regulation, education, infrastructure provision, etc.). However, it is also true that economic water management tools remain some of our most important instruments available in helping to share water and manage water demand and supply.

5 References

ACCC (2021), *Murray-Darling Basin water markets enquiry: Final report*, Australian Competition and Consumer Commission, Canberra.

Ahlers, R. et al. (2014), "Informal space in the urban waterscape: Disaggregation and co-production of water services", *Water Alternatives*, Vol. 7/1, pp. 1–14.

Alevy, J.E., O. Cristi and O. Melo (2010), "Right-to-choose auctions: A field study of water markets in the Limari valley of Chile", *Agricultural and Resource Economics Review*, Vol. 39/2, pp. 213–226.

Allcott, H. (2011), "Social norms and energy conservation", *Journal of Public Economics*, Vol. 95/9–10, pp. 1082–1095.

Ambec, S. et al. (2016), "Review of international best practices for charges for water management", *OECD commissioned Background Paper*, Toulouse School of Economics.

Andrés, L.A. et al. (2008), "The impact of private sector participation in infrastructure: Lights, shadows, and the road ahead", *Latin American Development Forum Series*, World Bank, Washington, DC.

Andrés, L.A. et al. (2019), *Doing more with less: Smarter subsidies for water supply and sanitation*, World Bank, Washington, DC.

Andrés, L.A. et al. (2021), *Troubled tariffs: Revisiting water pricing for affordable and sustainable water services*, World Bank, Washington, DC.

Angel-Urdinola, D. and Q. Wodon (2011), "Does increasing access to infrastructure services improve the targeting performance of water subsidies?", *Journal of International Development*, Vol. 24/1, pp. 88–101.

Bajaj, A., S. Singh and D. Nayak (2022), "Impact of water markets on equity and efficiency in irrigation water use: A systematic review and meta-analysis", *Agricultural Water Management*, Vol. 259, 107182, https://doi.org/10.1016/j.agwat.2021.107182.

Bakker, K. (2002), "From state to market? Water mercantilización in Spain", *Environment and Planning A*, Vol. 34/5, pp. 767–790.

Bakker, K. (2007), "The 'commons' versus the 'commodity': Alter-globalization, anti-privatization and the human right to water in the global south", *Antipode*, Vol. 39, pp. 430–455.

Banerjee, S. et al. (2010), "Cost recovery, equity and efficiency in water tariffs: Evidence from African utilities", *Policy Research Working Paper*, Vol. 5384, World Bank, Washington, DC.

Barbier, E.B. (2019), *The Water Paradox: Overcoming the Global Crisis in Water Management*, Yale University Press, New Haven.

Barbier, E.B. (2022), "The economics of managing water crises", *Philosophical Transactions Royal Society A*, Vol. 380, p. 20210295, https://doi.org/10.1098/rsta.2021.0295.

Barde, J.A. and P. Lehmann (2014), "Distributional effects of water tariff reforms - An empirical study for Lima, Peru", *Water Resources and Economics*, Vol. 6, pp. 30–57.

Bate, R. (2002), "Water: Can property rights and markets replace conflict", in J. Morris (ed.), *Sustainable Development: Promoting Progress or Perpetuating Poverty*, Profile Books Press, London, UK.

Bauer, C. (2010), "Market approaches to water allocation: Lessons from Latin America", *Journal of Contemporary Water Research & Education*, Vol. 144/1, pp. 44–49.

Bauer, C.J. (2015), "Water conflicts and entrenched governance problems in Chile's market model", *Water Alternatives*, Vol. 8/2.

Becker, N. and N. Zeitouni (1998), "A market solution for the Israeli-Palestinian water dispute", *Water International*, Vol. 23/4, pp. 1–5.

Bell, S. and J. Quiggin (2008), "The limits of markets: The politics of water management in rural Australia", *Environmental Politics*, Vol. 17, pp. 712–729.

Bjornlund, H. (2003), "Efficient water market mechanisms to cope with water scarcity", *Water Resources Development*, Vol. 19/4, pp. 553–567.

Bjornlund, H. and J. McKay (2000), "Do water markets promote a socially equitable reallocation of water? A case study of a rural water market in Victoria, Australia", *Rivers*, Vol. 7/2, pp. 141–154.

BLS (2019), *Consumer Price Index for All Urban Consumers (CPI-U): U.S. City Average, by Expenditure Category*, US Bureau of Labor Statistics, Washington, DC.

BoM (2022), *Australian Water Markets Report 2020–21*, Bureau of Meteorology, Australian Government, Canberra.

Borzutzky, S. and E.F. Madden (2013), "Markets awash: The privatization of Chilean water markets", *Journal of International Development*, Vol. 25/2, pp. 251–275.

Brennan, D. (2006), "Water policy reform in Australia: Lessons from the Victorian seasonal water market", *Australian Journal of Agricultural and Resource Economics*, Vol. 50/3, pp. 403–423.

Brent, D.A. and M.B. Ward (2019), "Price perceptions in water demand", *Journal of Environmental Economics and Management*, Vol. 98, p. 102266.

Breviglieri, G.V., G.I. do Sol Osório and J.A. Puppim de Oliveira (2018), "Understanding the emergence of water market institutions: Learning from functioning water markets in three countries", *Water Policy*, Vol. 20/6, pp. 1075–1091.

Briscoe, J., P. Anguita Salas and T.H. Peña (1998), "Managing water as an economic resource: Reflections on the Chilean experience", *Environmental Economics Series*, World Bank, Washington, DC.

Broadbent, C.D. et al. (2014), "An experimental analysis of water leasing markets focusing on the agricultural sector", *Agricultural Water Management*, Vol. 142, pp. 88–98.

Brouwer, R. and N. Neverre (2020), "A global meta-analysis of groundwater quality valuation studies", *European Review of Agricultural Economics*, Vol. 47/3, pp. 893–932.

Brozovic, N., J.M. Carey and D.L. Sunding (2002), "Trading activity in an informal agricultural water market: An example from California", *Journal of Contemporary Water Research & Education*, Vol. 121/1, p. 2.

Burness, H.S. and J.P. Quirk (1980), "Water law, water transfers, and economic efficiency: The Colorado River", *The Journal of Law and Economics*, Vol. 23/1, pp. 111–134.

Cain, A. (2018), "Informal water markets and community management in peri-urban Luanda, Angola", *Water International*, Vol. 43/2, pp. 205–216.

Carey, J., D.L. Sunding and D. Zilberman (2002), "Transaction costs and trading behavior in an immature water market", *Environment and Development Economics*, pp. 733–750.

Chong, H. and D. Sunding (2006), “Water markets and trading”, *Annual Review of Environment and Resources*, Vol. 31, pp. 239–264.

Chu, L. and R.Q. Grafton (2021), “Dynamic water pricing and the risk adjusted user cost (RAUC)”, *Water Resources and Economics*, Vol. 35, p. 100181.

Cristi, O. (2011), “Análysis del mercado de agua”, *Conference Proyecto: Mercado Electronico Del Agua (MEDA)*, Santiago.

Culp, P.W., R.J. Glennon and G. Libecap (2014), *Shopping for water: How the market can mitigate water shortages in the American West*, Island Press.

Dellapenna, J.W. (2000), “The importance of getting names right: The myth of markets for water”, *William & Mary Environmental Law and Policy Review*, Vol. 25, pp. 317–377.

Di, D. et al. (2020), “Optimal water distribution system based on water rights transaction with administrative management, marketization, and quantification of sediment transport value: A case study of the Yellow River Basin, China”, *Science of the Total Environment*, Vol. 722, p. 137801.

Donohew, Z. (2009), “Property rights and western United States water markets”, *Australian Journal of Agricultural and Resource Economics*, Vol. 53/1, pp. 85–103.

Donoso, G. et al. (2021), “Assessment of water markets in Chile”, in S.A. Wheeler (ed.), *Water Markets: A Global Assessment* (pp. 270–283), Edward Elgar Publishing.

Easter, K. and Q. Huang (2014), *Water markets for the 21st Century*, Springer.

Easter, K.W., M.W. Rosegrant and A. Dinar (eds.). (1998), *Markets for water: Potential and performance*, Springer US, Boston, MA, https://doi.org/10.1007/b102479.

Erfani, T., O. Binions and J.J. Harou (2014), “Simulating water markets with transaction costs”, *Water Resources Research*, Vol. 50/6, pp. 4726–4745.

Fielding, K.S. et al. (2013), “An experimental test of voluntary strategies to promote urban water demand management”, *Journal of Environmental Management*, Vol. 114, pp. 343–351.

Freebairn, J. (2005), “Issues in the Design of Water Markets”, *Melbourne Institute Working Paper Series, Working Paper*, Vol. 18/5, https://melbourneinstitute.unimelb.edu.au/downloads/working_paper_series/wp2005n18.pdf.

Fuente, D. et al. (2016), “Water and sanitation service delivery, pricing, and the poor: An empirical estimate of subsidy incidence in Nairobi, Kenya”, *Water Resources Research*, Vol. 52/6, pp. 4845–4862.

Garcia, S., L. Guérin-Schneider and G. Fauquert (2005), “Analysis of water price determinants in France: Cost recovery, competition for the market and operator’s strategy”, *Water Science and Technology: Water Supply*, Vol. 5/6, pp. 173–181.

García-Valiñas, M.Á., R. Martínez-Espiñeira and M. Suárez-Varela Maciá (2021), “Price and consumption misperception profiles: The role of information in the residential water sector”, *Environmental and Resource Economics*, Vol. 80, pp. 821–857.

García-Valiñas, M.Á. and S. Suárez-Fernández (2022), “Are economic tools useful to manage residential water demand? A review of old issues and emerging topics”, *Water*, Vol. 14, p. 2536.

Garrick, D. et al. (2019), “Rural water for thirsty cities: A systematic review of water reallocation from rural to urban regions”, *Environmental Research Letters*, Vol. 14/4, p. 043003.

Garrick, D. and B. Aylward (2012), "Transaction costs and institutional performance in market-based environmental water allocation", *Land Economics*, Vol. 88/3, pp. 536–560.

Garrick, D., S.M. Whitten and A. Coggan (2013), "Understanding the evolution and performance of water markets and allocation policy: A transaction costs analysis framework", *Ecological Economics*, Vol. 88, pp. 195–205.

Ghosh, S. (2019), "Droughts and water trading in the western United States: Recent economic evidence", *International Journal of Water Resources Development*, Vol. 35/1, pp. 145–159.

Giannoccaro, G., M. Castillo and J. Berbel (2015), "An assessment of farmers' willingness to participate in water trading in southern Spain", *Water Policy*, Vol. 17/3, pp. 520–537.

Glennon, R. (2004), "Water scarcity, marketing, and privatization", *Texas Law Review*, Vol. 83, p. 1873.

Glennon, R. (2015), *Should farm communities support water markets?*, Western Farm Press.

Grafton, R.Q. et al. (2011), "An integrated assessment of water markets: A cross-country comparison", *Review of Environmental Economics and Policy*, Vol. 5, pp. 219–239.

Grafton, R.Q. et al. (2011), "Determinants of residential water consumption: Evidence and analysis from a 10-country household survey", *Water Resources Research*, Vol. 47, pp. 1–14.

Grafton, R.Q. et al. (2018), "The paradox of irrigation efficiency", *Science*, Vol. 361/6404, pp. 748–750.

Grafton, R.Q., L. Chu and P. Wyrwoll (2020), "The paradox of water pricing: Dichotomies, dilemmas, and decisions", *Oxford Review of Economic Policy*, Vol. 36/1, pp. 86–107.

Grafton, R.Q., D. Garrick and J. Horne (2017), "Water misallocation: Governance challenges and responses", *Report prepared for World Bank*.

Grafton, R.Q. and J. Horne (2014), "Water markets in the Murray-Darling basin", *Agricultural Water Management*, Vol. 145, pp. 61–71.

Grafton, R.Q., J. Horne and S.A. Wheeler (2016), "On the marketisation of water: Evidence from the Murray-Darling Basin, Australia", *Water Resources Management*, Vol. 30/3, pp. 913–926.

Grafton, R.Q., J. Horne and S.A. Wheeler (2022), "Rethinking water markets", *Oxford Research Encyclopedias, Environmental Science*, https://doi.org/10.1093/acrefore/9780199389414.013.800.

Grafton, R.Q. and M. Ward (2008), "Prices versus rationing: Marshallian surplus and mandatory water restrictions", *Economic Record*, Vol. 84/s1, pp. 57–65.

Grafton, R.Q. and S.A. Wheeler (2015), "Water economics", in R. Halvorsen & D. Layton (eds.), *Handbook on the Economics of Natural Resources*, Edward Elgar Publishing.

Grafton, R.Q. and S.A. Wheeler (2018), "Economics of water recovery in the Murray-Darling Basin, Australia", *Annual Review of Resource Economics*, Vol. 10, pp. 487–510.

Griffin, R.C. (2006), *Water Resource Economics: The Analysis of Scarcity, Policies, and Projects*, The MIT Press, Cambridge, Mass.

Griffin, R.C., D. Peck and J. Maestu (2013), "Introduction: Myths, principles and issues in water trading", in J. Maestu (ed.), *Water Trading and Global Water Scarcity: International experiences* (pp. 1–14), RFF Press Water Policy Series.

Gruère, G. and M. Shigemitsu (2021), "Measuring progress in agricultural water management: Challenges and practical options", *OECD Food, Agriculture and Fisheries Papers* (Volume 162), OECD Publishing, Paris, https://doi.org/10.1787/52b4db7e-en.

Gruère, G., M. Shigemitsu and S. Crawford (2020), "Agriculture and water policy changes: Stocktaking and alignment with OECD and G20 recommendations", *OECD Food, Agriculture and Fisheries Papers* (Volume 144), OECD Publishing, Paris, https://doi.org/10.1787/f35e64af-en.

Gulyani, S., D. Talukdar and R. Mukami Kariuki (2005), "Universal (non) service? Water markets, household demand and the poor in urban Kenya", *Urban Studies*, Vol. 42/8, pp. 1247–1274.

Hadjigeorgalis, E. and J. Lillywhite (2004), "The impact of institutional constraints on the Limarí River Valley water market", *Water Resources Research*, Vol. 40/5, https://doi.org/10.1029/2003WR002701.

Hall, J.W. et al. (2014), "Coping with the curse of freshwater variability", *Science*, Vol. 346/6208, pp. 429–430.

Hamilton, S. and S. Kells (2021), *Sold Down the River: How Robber Barons and Wall Street Traders Cornered Australia's Water Warket*, The Text Publishing Company, Melbourne, Australia.

Hanemann, M. (2005), *The value of water*. Working Paper., Berkeley: University of California at Berkeley.

Hanemann, W.H. (2006), "The economic conception of water", in P.P. Rogers, M.R. Llamas & L. Martinez-Cortina (eds.), *Water Crisis: Myth or Reality?*, Taylor & Francis plc.

Hansen, K., J. Kaplan and S. Kroll (2014), "Valuing options in water markets: A laboratory investigation", *Environmental and Resource Economics*, Vol. 57/1, pp. 59–80.

Hearne, R. and G. Donoso (2014), *Water markets in Chile: Are they meeting needs?*, (K. Easter & Q. Huang, Eds.), Springer, Dordrecht.

Heerden, J.H., J. Blignaut and M. Horridge (2008), "Integrated water and economic modelling of the impacts of water market instruments on the South African economy", *Ecological Economics*, Vol. 66/1, pp. 105–116.

Houtven, G., J. Powers and S.K. Pattanayak (2007), "Valuing water quality improvements in the United States using meta-analysis: Is the glass half-full or half-empty for national policy analysis?", *Resource and Energy Economics*, Vol. 29, pp. 206–228.

Howe, C.W., D.R. Schurmeier and W.D. Shaw Jr (1986), "Innovative approaches to water allocation: The potential for water markets", *Water Resources Research*, Vol. 22, pp. 439–445.

Howitt, R.E. (1994), "Empirical analysis of water market institutions: The 1991 California water market", *Resource and Energy Economics*, Vol. 16/4, pp. 357–371.

Hung, M.F., D. Shaw and B.T. Chie (2014), "Water trading: Locational water rights, economic efficiency, and third-party effect", *Water*, Vol. 6/3, pp. 723–744.

Ipe, V.C. and S.B. Bhagwat (2002), "Chicago's water market: Dynamics of demand, prices and scarcity rents", *Applied Economics*, Vol. 34/17, pp. 2157–2163.

Ito, K. (2014), "Do consumers respond to marginal or average price? Evidence from nonlinear electricity pricing", *American Economic Review*, Vol. 104/2, pp. 537–563.

Jaghdani, T. and B. Brümmer. (2016), "Determinants of willingness to pay for groundwater: Insights from informal water markets in Rafsanjan, Iran", *International Journal of Water Resources Development*, Vol. 32/6, pp. 944–960.

Jamshidi, S., M. Ardestani and M. Hossein Niksokhan. (2016), "A seasonal waste load allocation policy in an integrated discharge permit and reclaimed water market", *Water Policy*, Vol. 18/1, pp. 235–250, https://doi.org/10.2166/wp.2015.301.

Jiang, M. et al. (2020), "Beyond contradiction: The state and the market in contemporary Chinese water governance", *Geoforum*, Vol. 108, pp. 246–254.

Johnson, D.D. (1971), "An optimal state water law: Fixed water rights and flexible market prices", *Virginia Law Review*, pp. 345–374.

Kahil, M.T., A. Dinar and J. Albiac. (2015), "Modeling water scarcity and droughts for policy adaptation to climate change in arid and semiarid regions", *Journal of Hydrology*, Vol. 522, pp. 95–109.

Keulertz, M. and T. Allan. (2017), "What is food-water and why do we not account for it?", in K. Conca & E. Weinthal (eds.), *The Oxford Handbook of Water Politics and Policy* (Volume 1), Oxford University Press, https://doi.org/10.1093/oxfordhb/9780199335084.013.1.

Keulertz, M. and P. Riddell. (2022), "Chronic crisis: 30 years on from the Dublin Principles and still no market to value water", *Water International*, Vol. 47, pp. 1048–1059.

Kirsch, B.R. and R.M. Maxwell. (2015), "The use of a water market to minimize drought-induced losses in the Bay area of California", *Journal – American Water Works Association*, Vol. 107/5, pp. 274–281.

Komives, K. et al. (2005), *Water, electricity, and the poor: Who benefits from utility subsidies? Directions in Development*, World Bank, Washington, DC.

Lee, L.Y., T. Ancev and W. Vervoort. (2007), "Environmental and economic impacts of water scarcity and market reform on the Mooki catchment", *The Environmentalist*, Vol. 27/1, pp. 39–49.

Lefebvre, M., L. Gangadharan and S. Thoyer. (2012), "Do security-differentiated water rights improve the performance of water markets?", *American Journal of Agricultural Economics*, Vol. 94/5, pp. 1113–1135.

Leonard, B., C. Costello and G.D. Libecap. (2019), "Expanding water markets in the western United States: Barriers and lessons from other natural resource markets", *Review of Environmental Economics and Policy*, Vol. 13/1, pp. 43–61.

Loch, A., H. Bjornlund and R. McIver. (2011), "Achieving targeted environmental flows: Alternative allocation and trading models under scarce supply - lessons from the Australian reform process", *Environment and Planning C: Government and Policy*, Vol. 29/4, pp. 745–760.

Loch, A., S.A. Wheeler and C. Settre. (2018), "Private transaction costs of water trade in the Murray–Darling Basin", *Ecological Economics*, Vol. 146, pp. 560–573.

Louw, D.B. and H.D. Schalkwyk. (2001), "The impact of transaction costs on water trade in a water market allocation regime", *Agrekon*, Vol. 40/4, pp. 780–793.

MacDonald, D.H. et al. (2011), "Valuing a multistate river: The case of the river Murray", *The Australian Journal of Agricultural and Resource Economics*, Vol. 55, pp. 374–392.

Maestu, J. (ed.). (2012), *Water Trading and Global Water Scarcity: International Experiences*, Routledge, London, https://doi.org/10.4324/9780203084151.

Mahan, R.C., T.M. Horbulyk and J.G. Rowse. (2002), "Market mechanisms and the efficient allocation of surface water resources in southern Alberta", *Socio-Economic Planning Sciences*, Vol. 36/1, pp. 25–49.

Manjunatha, A.V. et al. (2011), "Impact of groundwater markets in India on water use efficiency: A data envelopment analysis approach", *Journal of Environmental Management*, Vol. 92/11, pp. 2924–2929.

Marin, P. (2009), *Public-private partnerships for urban water utilities - A review of experiences in developing countries. Trends and policy options No.8*, World Bank, Washington, DC.

Matchaya, G. et al. (2019), "An overview of water markets in southern Africa: An option for water management in times of scarcity", *Water*, Vol. 11/5, p. 1006.

Matthews, O.P. (2004), "Fundamental questions about water rights and market reallocation", *Water Resources Research*, Vol. 40/9.

McCarl, B.A. et al. (1999), "Limiting pumping from the Edwards Aquifer: An economic investigation of proposals, water markets, and spring flow guarantees", *Water Resources Research*, Vol. 35/4, pp. 1257–1268.

McKenzie, M. (2009), "Water rights in NSW: Properly property?", *Sydney Law Review*, Vol. 31, p. 443.

Michelsen, A.M. and R.A. Young. (1993), "Optioning agricultural water rights for urban water supplies during drought", *American Journal of Agricultural Economics*, Vol. 75/4, pp. 1010–1020.

Möller-Gulland, J. and G. Donoso (2016), "A typology of water market intermediaries", *Water International*, Vol. 41/7, pp. 1016–1034.

Munala, G. and H. Kainz (2012), "Managing interactions in the informal water market: The case of Kisumu, Kenya", *Development in Practice*, Vol. 22/3, pp. 347–360.

Nauges, C., S.A. Wheeler and A. Zuo (2016), "Elicitation of irrigators' risk preferences from observed behaviour", *Australian Journal of Agricultural Resource Economics*, Vol. 60/3, pp. 442–458.

Nauges, C. and D. Whittington (2010), "Estimation of water demand in developing countries: An overview", *World Bank Research Observer*, Vol. 25/2, pp. 263–294.

Nauges, C. and D. Whittington (2017), "Evaluating the performance of alternative municipal water tariff designs: Quantifying the trade-offs between equity, economic efficiency, and cost recovery", *World Development*, Vol. 91, pp. 125–143.

Nauges, C. and D. Whittington (2019), "Social norms information treatments in the municipal water supply sector: Some new insights on benefits and costs", *Water Economics and Policy*, Vol. 5/3, p. 1850026.

Neuman, J.C. and C. Chapman (1999), "Wading into the water market: The first five years of the years of the Oregon water trust", *Journal of Environmental Law and Litigation*, Vol. 14, p. 135.

Newlin, B.D. et al. (2002), "Southern California water markets: Potential and limitations", *Journal of Water Resources Planning and Management*, Vol. 128/1, pp. 21–32.

Nieuwoudt, W.L. (2000), "Water market institutions: Lessons from Colorado", *Agrekon*, Vol. 39/1, pp. 58–67.

Nieuwoudt, W.L. and R.M. Armitage (2004), "Water market transfers in South Africa: Two case studies", *Water Resources Research*, Vol. 40/9, pp. 1–9.

Nikolakis, W. and R.Q. Grafton (2015), "Putting Indigenous water rights to work: The Sustainable Livelihoods Framework as a lens for remote development", *Community Development*, Vol. 46/2, pp. 149–163.

Nikolakis, W.D., R.Q. Grafton and H. To (2013), "Indigenous values and water markets: Survey insights from northern Australia", *Journal of Hydrology*, Vol. 500, pp. 12–20.

Nordblom, T.L. et al. (2011), "Price discovery and distribution of water rights linking upstream tree plantations to downstream water markets: Experimental results", *Water Policy*, Vol. 13/6, pp. 810–827.

OECD (2010), *Sustainable Management of Water Resources in Agriculture*, Organisation for Economic Co-operation and Development, Paris.

OECD (2015), *Water Resources Allocation: Sharing Risks and Opportunities*, OECD Studies on Water, OECD Publishing, Paris.

OECD (2017), "Policy Instrument Database 2017", OECD Publishing, Paris, https://www.oecd.org/environment/indicators-modelling-outlooks/policy-instrument-database/.

OECD (2021), *Water Governance in African Cities*, OECD Studies on Water, OECD Publishing, Paris.

Perry, C. (2013), "ABCDE+ F: A framework for thinking about water resources management", *Water International*, Vol. 38/1, pp. 95–107.

Petterini, F.C. (2018), "The possibility of a water market in Brazil", *Economia*, Vol. 19/2, pp. 187–200.

Poirier, R. and D. Schartmueller (2012), "Indigenous water rights in Australia", *The Social Science Journal*, Vol. 49/3, pp. 317–324.

Porten, S. and R.C. Loë (2014), "Water policy reform and Indigenous governance", *Water Policy*, Vol. 16/2, pp. 222–243.

Prieto, M. (2016), "Bringing water markets down to Chile's Atacama Desert", *Water International*, Vol. 41/2, pp. 191–212.

Pujol, J., M. Raggi and D. Viaggi (2006), "The potential impact of markets for irrigation water in Italy and Spain: A comparison of two study areas", *Australian Journal of Agricultural and Resource Economics*, Vol. 50/3, pp. 361–380.

Pullen, J.L. and B.G. Colby (2008), "Influence of climate variability on the market price of water in the Gila-San Francisco Basin", *Journal of Agricultural and Resource Economics*, pp. 473–487.

Raffensperger, J.F. (2011), "Matching users' rights to available groundwater", *Ecological Economics*, Vol. 70/6, pp. 1041–1050, https://doi.org/10.1016/j.ecolecon.2011.01.015.

Raina, A. et al. (2019), "The structure of water vending markets in Kathmandu, Nepal", *Water Policy*, Vol. 21/S1, pp. 50–75.

Rambonilaza, T. and M. Neang (2019), "Exploring the potential of local market in remunerating water ecosystem services in Cambodia: An application for endogenous attribute non-attendance modelling", *Water Resources and Economics*, Vol. 25, pp. 14–26.

Ranjan, R. and J.F. Shogren. (2006), "How probability weighting affects participation in water markets", *Water Resources Research*, Vol. 42/8.

Razzaq, A. et al (2019), "Can the informal groundwater markets improve water use efficiency and equity? Evidence from a semi-arid region of Pakistan", *Science of The Total Environment*, Vol. 666, pp. 849–857.

Regnacq, C., A. Dinar and E. Hanak (2016), "The gravity of water: Water trade frictions in California", *American Journal of Agricultural Economics*, Vol. 98/5, pp. 1273–1294.

Renwick, M.E. and S.O. Archibald (1998), "Demand side management policies for residential water use: Who bears the conservation burden?", *Land Economics*, Vol. 74, pp. 343–359.

Reynaud, A. (2016), "Assessing the impact of full cost recovery of water services on European households", *Water Resources and Economics*, Vol. 14, pp. 65–78.

Ríos, M.A. and J.A. Quiroz (1995), "The market of water rights in Chile: Major issues", *Cuadernos de Economía*, Vol. 32/97, pp. 317–345.

Rodgers, A.B. (1986), “The limits of state activity in the interstate water market”, *Land & Water Law Review*, Vol. 21, p. 357.

Roibás, D., M.A. Garcia-Valiñas and A. Wall (2007), “Measuring welfare losses from interruption and pricing as responses to water shortages: An application to the case of Seville”, *Environmental and Resource Economics*, Vol. 38/2, pp. 213–229.

Roibás, D., M.A. Garcia-Valiñas and R. Fernandez-Llera (2019), “Measuring the impact of water supply interruptions on household welfare”, *Environmental and Resource Economics*, Vol. 73, pp. 159–179.

Rosegrant, M.W. and H.P. Binswanger (1994), “Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation”, *World Development*, Vol. 22/11, pp. 1613–1625.

Rosegrant, M.W., R.G. Schleyer and S.N. Yadav (1995), “Water policy for efficient agricultural diversification: Market-based approaches”, *Food Policy*, Vol. 20/3, pp. 203–223.

Russell, S. and K. Fielding (2010), “Water demand management research: A psychological perspective”, *Water Resources Research*, Vol. 46, pp. 1–12.

Sadoff, C.W. et al. (2015), “Securing water, sustaining growth”, *Report of the GWP/OECD Task Force on Water Security and Sustainable Growth*, University of Oxford, UK.

Saleth, R.M. and A. Dinar (2001), “Preconditions for market solution to urban water scarcity: Empirical results from Hyderabad City, India”, *Water Resources Research*, Vol. 37/1, pp. 119–131.

Sayre, S.S. and V. Taraz (2019), “Groundwater depletion in India: Social losses from costly well deepening”, *Journal of Environmental Economics and Management*, Vol. 93, pp. 85–100.

Schwabe, K. et al. (2020), “Water markets in the Western United States: Trends and opportunities”, *Water*, Vol. 12/1, p. 233.

Seidl, C., S.A. Wheeler and A. Zuo (2020), “Treating water markets like stock markets: Key water market reform lessons in the Murray-Darling Basin”, *Journal of Hydrology*, Vol. 581, p. 124399.

Shatanawi, M.R. and O. Al-Jayousi (1995), “Evaluating market-oriented water policies in Jordan: A comparative study”, *Water International*, Vol. 20/2, pp. 88–97.

Shupe, S.J., G.D. Weatherford and E. Checchio (1989), “Western water rights: The era of reallocation”, *Natural Resources Journal*, Vol. 29, p. 413.

Sima, L.C. et al. (2013), “Water flows, energy demand, and market analysis of the informal water sector in Kisumu, Kenya”, *Ecological Economics*, Vol. 87, pp. 137–144.

Solanes, M. and A. Jouravlev (2006), “Water rights and water markets: Lessons from technical advisory assistance in Latin America”, *Irrigation and Drainage: The Journal of the International Commission on Irrigation and Drainage*, Vol. 55/3, pp. 337–342.

Svensson, J. et al. (2021), “How does hybrid environmental governance work? Examining water rights trading in China (2000–2019”, *Journal of Environmental Management*, Vol. 288, p. 112333.

Svensson, S., D. Garrick and S. Jia (2019), “Water markets as coupled infrastructure systems: Comparing the development of water rights and water markets in Heihe, Shiyang and Yellow Rivers”, *Water International*, Vol. 44/8, pp. 834–853.

Taylor, K.S., B.J. Moggridge and A. Poelina (2016), "Australian Indigenous water policy and the impacts of the ever-changing political cycle", *Australasian Journal of Water Resources*, Vol. 20/2, pp. 132–147, https://doi.org/10.1080/13241583.2017.1348887.

Tewari, D. (2005), "A brief historical analysis of water rights in South Africa", *Water International*, Vol. 30/4, pp. 438–445.

Tewari, D. (2017), *Water Markets in South Africa: Are They Working or Will They Work?*, University of Zululand: KwaDlangezwa.

Tinbergen, J. (1952), *On the Theory of Economic Policy*, North-Holland, New York.

Tisdell, J.G. (2001), "The environmental impact of water markets: An Australian case-study", *Journal of Environmental Management*, Vol. 62/1, pp. 113–120.

Turral, H.N. et al. (2005), "Water trading at the margin: The evolution of water markets in the Murray-Darling Basin", *Water Resources Research*, Vol. 41/7.

Uchida, E. et al. (2018), "Integrating watershed hydrology and economics to establish a local market for water quality improvement: A field experiment", *Ecological Economics*, Vol. 146, pp. 17–25.

United Nations Statistics Division (2012), *System of Environmental-Economic Accounting for Water*, United Nations, New York.

Utton, A.E. (1985), "In search of an integrating principle for interstate water law: Regulation versus the market place", *Natural Resources Journal*, Vol. 25/4, pp. 985–1004.

Vasquez, J. (2008), "Feasibility of a water market in Colombia", *International Journal of Sustainable Development and Planning*, Vol. 3/4, pp. 394–400.

Venkatachalam, L. (2015), "Informal water markets and willingness to pay for water: A case study of the urban poor in Chennai City, India", *International Journal of Water Resources Development*, Vol. 31/1, pp. 134–145.

Vij, S., A. John and A. Barua (2019), "Whose water? Whose profits? The role of informal water markets in groundwater depletion in peri-urban Hyderabad", *Water Policy*, Vol. 21/5, pp. 1081–1095.

Vörösmarty, C.J. et al. (2010), "Global threats to human water security and river biodiversity", *Nature*, Vol. 467/7315, pp. 555–561.

Wang, J. and J.M. Chermak (2021), "Is less always more? Conservation, efficiency, and water education programs", *Ecological Economics*, Vol. 184, p. 106994.

Wheeler, S.A. et al. (2008a), "Factors influencing water allocation and entitlement prices in the Greater Goulburn Area of Australia", in Y. Villacampa, C.A. Brebbia & D.P. Rico (eds.), *Sustainable Irrigation Management, Technologies and Policies II* (pp. 63–71 ,), WIT Press.

Wheeler, S.A. et al. (2008b), "Price elasticity of water allocations demand in the Goulburn-Murray Irrigation District", *Australian Journal of Agricultural and Resource Economics*, Vol. 52/1, pp. 37–55.

Wheeler, S.A. et al. (2009), "Who trades water allocations? Evidence of the characteristics of early adopters in the Goulburn-Murray Irrigation District, Australia 1998–1999", *Agricultural Economics*, Vol. 40/6, pp. 631–643.

Wheeler, S.A. et al. (2010), "The changing profile of water traders in the Goulburn-Murray Irrigation District, Australia", *Agricultural Water Management*, Vol. 97/9, pp. 1333–1343.

Wheeler, S.A. et al. (2013), "Evaluating water market products to acquire water for the environment in Australia", *Land Use Policy*, Vol. 30/1, pp. 427–436.

Wheeler, S.A. (2014), "Insights, lessons and benefits from improved regional water security and integration in Australia", *Water Resources and Economics*, Vol. 8, pp. 57–78.

Wheeler, S.A. et al. (2014), "Reviewing the adoption and impact of water markets in the Murray–Darling Basin, Australia", *Journal of Hydrology*, Vol. 518, pp. 28–41.

Wheeler, S.A. et al. (2017), "Developing a water market readiness assessment framework", *Journal of Hydrology*, Vol. 552, pp. 807–820.

Wheeler, S.A. et al. (2020), "The rebound effect on water extraction from subsidising irrigation infrastructure in Australia", *Resources, Conservation and Recycling*, Vol. 159, p. 104755.

Wheeler, S.A. (2021), "Lessons from water markets around the world", in S.A. Wheeler (ed.), *Water Markets: A Global Assessment* (pp. 270–283 ,), Edward Elgar Publishing.

Wheeler, S.A. (2022), "Debunking Murray-Darling Basin water trade myths", *The Australian Journal of Agricultural and Resource Economics*, https://doi.org/10.1111/1467-8489.12490.

Wheeler, S.A. et al. (2022), "Exploring the economic values of the Murray-Darling Basin and rating the quality assessment of water recovery economic studies", *Report prepared for the Murray-Darling Basin Authority, November 2022*.

Wheeler, S.A. and D. Garrick (2020), "A tale of two water markets in Australia: Lessons for understanding participation in formal water markets", *Oxford Review of Economic Policy*, Vol. 36/1, pp. 132–153.

Wheeler, S.A. and Y. Xu (2021), "Introduction to water markets: An overview and systematic literature review", in S.A. Wheeler (ed.), *Water Markets: A Global Assessment* (pp. 1–19), Edward Elgar Publishing.

Whitford, A.B. and B.Y. Clark (2007), "Designing property rights for water: Mediating market, government, and corporation failures", *Policy Sciences*, Vol. 40/4, pp. 335–351.

Whittington, D. et al. (2015), "A diagnostic tool for estimating the incidence of subsidies delivered by water utilities in low- and medium-income countries, with illustrative simulations", *Utilities Policy*, Vol. 34, pp. 70–81.

WHO and UNICEF (2017), *Progress on drinking water, sanitation, and hygiene*, WHO and UNICEF, Geneva.

Wittwer, G. (2011), "Confusing policy and catastrophe: Buybacks and drought in the Murray–Darling basin", *The Economic Record*, Vol. 30/3, pp. 289–430.

Wittwer, G. and M.D. Young (2020), "Distinguishing between policy, drought and international events in the context of the Murray-Darling Basin plan", *Centre of Policy Studies/IMPACT Centre Working Papers*, Victoria University, Centre of Policy Studies/IMPACT Centre.

World Bank (2022), "The International Benchmarking Network for Water and Sanitation Utilities (IBNET)", *World Bank Water Data*, Washington, DC, https://wbwaterdata.org/ibnet.

Xu, C. et al. (2021), "Bargaining power and information asymmetry in China's water market: An empirical two-tier stochastic frontier analysis", *Empirical Economics*, Vol. 61/5, pp. 2395–2418.

Yoskowitz, D.W. (1999), "Spot market for water along the Texas Rio Grande: Opportunities for water management", *Natural Resources Journal*, pp. 345–355.

Yoskowitz, D.W. (2002), "Price dispersion and price discrimination: Empirical evidence from a spot market for water", *Review of Industrial Organization*, Vol. 20/3, pp. 283–289.

Young, M. (2014), *Trading into trouble? Lessons from Australia's mistakes in water policy reform sequencing*, (K.W. Easter & Q. Huang, Eds.), Springer, Dordrecht.

Young, M. (2019), *Sharing Water: The role of robust water-sharing arrangements in integrated water resources management*, Perspectives paper by Global Water Partnership.

Zarnikau, J. (1994), "Spot market pricing of water resources and efficient means of rationing water during scarcity (water pricing)", *Resource and Energy Economics*, Vol. 16/3, pp. 189–210.

Zarour, H. and J. Isaac (1993), "Nature's apportionment and the open market: A promising solution to the Arab-Israeli water conflict", *Water International*, Vol. 18/1, pp. 40–53.

Zavalloni, M., M. Raggi and D. Viaggi (2014), "Water harvesting reservoirs with internal water reallocation: A case study in Emilia Romagna, Italy", *Journal of Water Supply: Research and Technology—AQUA*, Vol. 63/6, pp. 489–496.

Zegarra, E. (2002), *Water market and coordination failures: The case of the Limari Valley in Chile*. PhD thesis., University of Wisconsin.

Zekri, S. and W. Easter (2005), "Estimating the potential gains from water markets: A case study from Tunisia", *Agricultural Water Management*, Vol. 72/3, pp. 161–175.

Zhang, J. et al. (2009), "Transaction costs in water markets in the Heihe River Basin in Northwest China", *International Journal of Water Resources Development*, Vol. 25/1, pp. 95–105.

Zhao, J., X. Cai and Z. Wang (2013), "Comparing administered and market-based water allocation systems through a consistent agent-based modeling framework", *Journal of Environmental Management*, Vol. 123, pp. 120–130.

Zilberman, D. and K. Schoengold (2005), "The use of pricing and markets for water allocation", *Canadian Water Resources Journal*, Vol. 30/1, pp. 47–54.

Zuin, V., L. Ortolano and J. Davis (2014), "The entrepreneurship myth in small-scale service provision: Water resale in Maputo, Mozambique", *Journal of Water, Sanitation and Hygiene for Development*, Vol. 4/2, pp. 281–292.

Zuo, A., F. Qiu and S. Wheeler (2019), "Examining volatility dynamics, spillovers and government water recovery in Murray-Darling Basin water markets", *Resource and Energy Economics*, Vol. 58, p. 101113.

Appendices

A.1 Water abstraction and pollution charges

A.1.1 Principles and implementation

Water users may impose costs on other water users and on the environment. For example, in regions where water is scarce, the abstraction of water for supplying urban users may impact the quantity available for irrigation purposes. The value of these foregone opportunities for alternative water users gives an indication of the resource or scarcity cost. Similarly, too much water abstraction can create irreversible damage to the environment, for example, when excessive groundwater extraction causes saline intrusion in coastal aquifers, or when the ecosystem of water streams is damaged due to reduced river flows or high water temperature. Water users may also pollute surface and groundwater. A typical example is the runoff of nutrients and pesticide residues after chemical inputs have been applied on crop fields or pastures.

Assessing the damage caused by water abstraction and water pollution is a difficult exercise, in particular for environmental damage. This is mainly because the environmental benefits of preserving a minimum water flow or reducing pollution are difficult to quantify and are not currently priced. In some cases, non-market valuation techniques (such as contingent valuation or travel cost studies) are implemented in order to put some economic value on hypothetical environmental benefits, but such studies are costly, and their findings may be quite site-specific and not easily transferable to other sites (see, among other examples of valuation studies: Brouwer and Neverre, 2020; MacDonald et al., 2011; Van Houtven et al., 2007). In addition to difficulty assessing the costs and damage induced by water abstraction and pollution, defining a tax base is also complicated.

The volume of water abstracted is usually chosen as the basis for taxation (Ambec et al., 2016). However, water metering is not universal, especially when water is used for irrigation purposes. Also, part of the water may be returned to the ground, with or without alteration of its quality. If part of the water abstracted is returned to the ground without any quality degradation, then charging water users on the basis of the amount abstracted (instead of the amount actually used) may not be fair. For uses which are not yet metered, other taxation bases may include hectares for irrigated areas or megawatt-hours for electricity production. The water abstraction charge is usually differentiated by water source (groundwater or surface water) and by the type of user (residential, industry, agriculture). The agricultural sector often benefits from lower rates or exemptions.

Pollutants going into water streams may be detrimental to human health and the environment. Consequently, polluters should be charged for the costs they impose on society. This is also a difficult task since pollution is diffuse and the damage is also often site-specific. Pollution sources are also not always easy to identify, particularly when pollutants are the outcome of nutrient runoff and pesticide use on crop fields. In such cases, one solution is to tax input factors, which are directly responsible for pollution. However, when the source of the pollution can be identified (for example residential or industrial uses), pollution charges are usually calculated based on volume and pollution content and differentiated according to the sector (e.g. industry or agriculture).

A.1.2 Examples of water abstraction and pollution charges

Before discussing examples of water abstraction and pollution charges implemented in some countries, it is important to get a broader perspective on the relative importance of such taxes. Water abstraction and pollution charges are classified among environmental taxes, which is one domain among others (air pollution, transport, energy efficiency, biodiversity, climate change, waste management, land and soil management, etc.). The OECD has built a database on environmentally related taxes in OECD countries (detailed statistics by country available at https://stats.oecd.org/).[5]

Environmentally related taxes represented 1.35% of GDP in the OECD as a whole and 2.27% for European OECD countries, with taxes on the purchase or use of motor vehicles and fuels, including taxes on petrol and diesel, generating most of the revenues. Figure A.1, sourced from the OECD presentation of the Policy Instruments for the Environment (PINE) database, illustrates the small share that water-related taxes and charges represent, among other environmentally related taxes, and as a percentage of GDP in a number of OECD countries, as of 2014.[6]

Some examples of water abstraction taxes/charges are provided below, taken from this OECD database. These charges are usually implemented by local (rather than national) governments. They commonly vary between groundwater and surface water, and between industries and/or specific uses. There is significant variation in tax levels. It is important to bear in mind that without knowing the details of their calculation their relevance and the comparison across locations remain quite difficult. Nevertheless, some examples include:

- In Belgium (Flanders), a tax on groundwater was set at EUR 0.0603 per m^3 (minimum rate for 2011).
- In Canada, states established water abstraction permit fees that vary across a large number of categories of uses. As examples for industrial activities, the fee varies between cooling operations (EUR 24.21 per 50,000 gallons a day or less) and food processing plants or sawmills (EUR 9.69 for 20,000 gallons a day or less). For (private) irrigation purposes, the fee is EUR 15.01 per 40 acre-feet a year or less.
- In China, a groundwater resource fee has been put in place and varies also between regions: EUR 0.5442 per m^3 in the Beijing and Tianjin area; EUR 0.2041 per m^3 in the Hebei, Shandong and Henan area, and EUR 0.0272 per m^3 in the Shanghai area.
- Costa Rica has implemented a water consumption charge that amounts to EUR 0.423 – 1.886 per m^3 for water delivered to households, and EUR 0.777 – 2.774 per m^3 for water delivered to industry.
- In Germany, the charge on groundwater abstraction varies across states: EUR 0.0511 per m^3 in Baden-Wuerttemberg, EUR 0.1020 per m^3 in Brandenburg, and EUR 0.3100 per m^3 in Berlin.

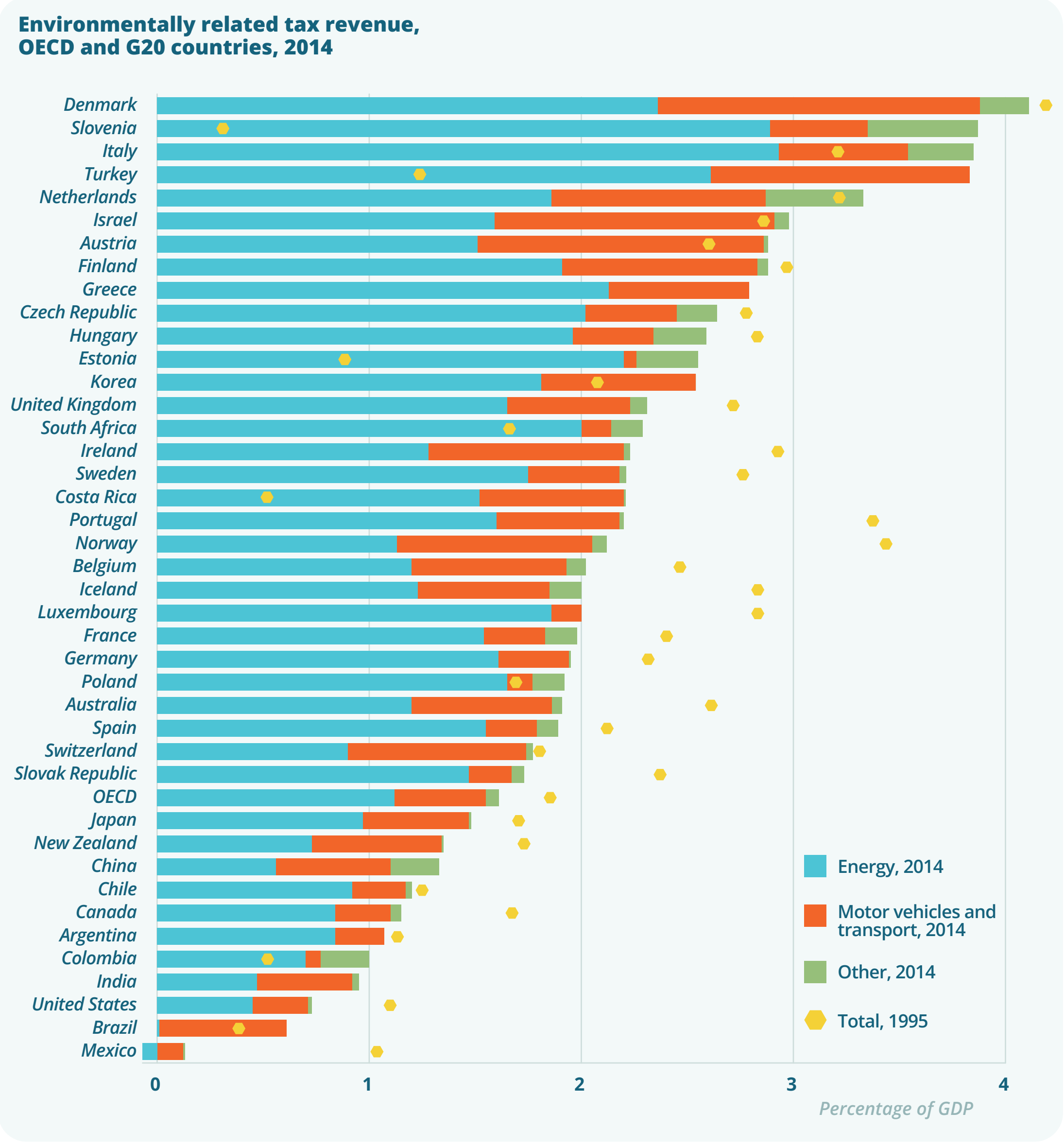
[5]From the OECD statistics webpage: "The OECD maintains a database of Policy Instruments for the Environment (PINE), originally developed in co-operation with the European Environment Agency (EEA). The database contains detailed qualitative and quantitative information on environmentally related taxes, fees and charges, tradable permits, deposit-refund systems, environmentally motivated subsidies and voluntary approaches used for environmental policy. The database is freely accessible at oe.cd/pine."

[6]Source: http://oe.cd/pine

- In the United Kingdom, there is a charge on water resource at EUR 0.0049 per m^3 on average.

Regarding pollution charges, they also vary significantly in terms of tax bases and tax levels across countries (or regions/states within countries). They are often differentiated by pollutants and based on tons of pollutants emitted. When targeting wastewater, the tax basis is usually the volume of water discharged.

Figure A.1 Environmentally related taxes among OECD and G20 countries (2014)



Source: Policy Instrument Database (OECD, 2017; p. 4)

A.2 Disparity of water prices across locations

Water prices are usually determined locally, either by municipal/local governments or by utilities. Prices thus usually vary within each country, from one city to another. Information on water prices is thus typically gathered for a subset of cities in each country. Apart from surveys designed and undertaken by independent researchers, there exist two commonly cited databases that gather information on water prices: the Global Water Tariff survey developed by Global Water Intelligence; and the International Benchmarking Network (IBNET) dataset built by the World Bank. The Global Water Tariff survey today gathers water tariffs for 569 cities across 186 countries. Access to this database requires a subscription fee. IBNET covers 219 countries and territories and 2,786 utilities. Access to the IBNET database, however, is free of charge. In what follows we report figures obtained from the IBNET database. One important limitation of these two databases is the selection of cities. Information on water tariffs is provided on a voluntary basis so there is no guarantee that the sample of cities is representative of each country. We also present average water prices by country (in current USD), weighted by population served and based on a consumption of 6 m^3 per month. Only a subset of countries has been selected. The full set of tariffs for all countries covered by IBNET can be found on their website: https://tariffs.ib-net.org/sites.

The average water prices (in current USD per cubic meter) vary significantly, even within regions gathering countries with comparable levels of development. In Europe for example, the average water price is at its highest in Northern countries (Denmark, Sweden and Germany record the three highest average prices), estimated at around 8 USD per cubic meter. On the contrary, countries from Southern Europe record lower average prices: USD 2.9 in Greece and USD 3.8 in Italy. Countries from North Africa (Algeria, Egypt, Libya) have among the lowest average prices, lower than USD 0.2.

Table A.1 Average water price in USD per m^3 based on a 6 m^3 consumption

Country	Price	Country	Price	Country	Price
Denmark	8.61	Uruguay	2.46	Mongolia	0.92
Sweden	7.85	Gibraltar	2.43	Paraguay	0.92
Germany	7.80	Malawi	2.37	Bolivia	0.91
Luxembourg	7.73	Botswana	2.27	Peru	0.91
Switzerland	7.40	Lesotho	2.23	Haiti	0.88
Australia	7.34	Dominican Republic	2.23	Honduras	0.87
Belgium	7.28	Gabon	2.18	China	0.86
UK. Scotland	7.20	Benin	2.10	Central African Rep.	0.85
Norway	7.11	Montenegro	2.03	Afghanistan	0.81
Finland	6.68	Bosnia and Herz.	2.01	Vietnam	0.79
Austria	5.93	Cameroon	1.97	Zambia	0.76
France	5.74	Djibouti	1.95	Taiwan	0.76
Spain	5.70	Costa Rica	1.93	Armenia	0.74
UK. England and Wales	5.61	Ghana	1.88	Sri Lanka	0.70
Czech Republic	5.50	Morocco	1.86	Liberia	0.64
Netherlands	5.26	Burkina Faso	1.83	Angola	0.63

Country	Price	Country	Price	Country	Price
Canada	5.22	South Korea	1.80	Bahrain	0.61
United States	5.10	Turkey	1.78	Guinea-Bissau	0.61
Iceland	4.95	Rwanda	1.78	Indonesia	0.60
Croatia	4.72	Jordan	1.73	Nigeria	0.52
New Zealand	4.58	Seychelles	1.67	Georgia	0.49
Cyprus	4.54	Mauritania	1.66	Chad	0.49
Portugal	4.20	Ecuador	1.62	Malaysia	0.47
Namibia	4.11	Colombia	1.59	Lebanon	0.46
Israel	4.05	Philippines	1.58	Tunisia	0.44
Slovakia	3.82	Cote d'Ivoire	1.58	Bangladesh	0.44
Italy	3.77	Brazil	1.55	Guinea	0.44
South Africa	3.59	Senegal	1.55	Ethiopia	0.41
Poland	3.59	Serbia	1.54	Argentina	0.37
Lithuania	3.58	Congo	1.53	Congo. Dem. Rep.	0.36
Slovenia	3.49	Mali	1.46	Cambodia	0.35
Japan	3.45	Kuwait	1.45	India	0.31
Singapore	3.42	Ukraine	1.45	Nicaragua	0.28
United Arab Emirates	3.33	Albania	1.44	Algeria	0.18
Romania	3.16	Kenya	1.40	Egypt	0.15
Latvia	3.16	Kosovo	1.40	Libya	0.14
Estonia	3.14	Eritrea	1.31	Pakistan	0.12
Bulgaria	3.06	Mozambique	1.29		
Greece	2.89	Guyana	1.21		
Oman	2.86	Togo	1.17		
Chile	2.83	Russia	1.16		
Andorra	2.80	Tanzania	1.13		
Hungary	2.77	Papua New Guinea	1.10		
Wallis and Futuna	2.76	Niger	1.09		
Nepal	2.73	Panama	1.07		
Tonga	2.58	Thailand	1.06		
Moldova	2.56	Guatemala	1.06		
Uganda	2.53	Hong Kong	1.02		
Zimbabwe	2.50	Mexico	0.92		

Source: IBNET database (World Bank, 2022).

A.3 Water market research topics and enabling requirements

Table A.2 Most common research topics in the water market literature

Research topic	Typical approach	Some examples (not exhaustive)
Feasibility of introducing water market(s) and framework assessment	Qualitative	Zarour and Isaac, 1993; Becker and Zeitouni, 1998; Bjornlund and McKay, 2000; Bjornlund, 2003; Bate, 2002; Vasquez, 2008; Grafton et al., 2011; Akran, 2013; Kirsch and Maxwell, 2015; Grafton et al., 2016; Prieto, 2016; Wheeler et al., 2017; Petterini, 2018
Water market performance	Qualitative and quantitative	McCarl et al., 1999; Neuman and Chapman, 1999; Mahan et al., 2002; Newlin et al., 2002; Zekri and Easter, 2005; Pujol et al., 2006; Bauer, 2010; Culp et al., 2014; Grafton and Horne, 2014; Mahan et al., 2014; Wheeler, 2014; Wheeler et al., 2014a; Bauer, 2015; Leonard et al., 2019
Privatisation and marketisation of the water sector	Qualitative	Glennon, 2004; Borzutzky and Madden, 2013; Glennon, 2015; Grafton et al., 2016
Water market policy evaluation	Qualitative and quantitative	Rosegrant et al., 1995; Brennan, 2006; van Heerden et al., 2008; Garrick and Aylward, 2012; Garrick et al., 2013; Jamshidi et al., 2016
Water demand and price analysis	Quantitative	Zarnikau, 1994; Saleth and Dinar, 2001; Ipe and Bhagwat, 2002; Yoskowitz, 2002; Garcia et al., 2005; Gulyani et al., 2005; Zilberman and Schoengold, 2005; Pullen and Colby, 2008; Wheeler et al., 2008; Zuo et al., 2019: Schwabe et al., 2020
Farmers' willingness to pay for water or participate in water market	Quantitative	Saleth and Dinar, 2001; Ranjan and Shogren, 2006; Giannoccaro et al., 2015; Venkatachalam, 2015; Jaghdani and Brümmer, 2016; Wheeler et al. 2009; 2010
Human behaviour in water markets	Quantitative (experimental)	Lefebvre et al., 2012; Broadbent et al., 2014; Hansen et al., 2014: Nauges et al., 2016
Institutional arrangements and transaction costs	Qualitative and quantitative	Howitt, 1994; Shatanawi and Al-Jayousi, 1995; Nieuwoudt, 2000; Carey et al., 2002; Hadjigeorgalis and Lillywhite, 2004; Zhang et al., 2009; Zhao et al., 2013; Erfani et al., 2014; Breviglieri, 2018; Loch et al., 2018
Case studies: water market successes and failures	Qualitative and quantitative	Burness et al., 1980; Yoskowitz, 1999; Bakker, 2002; Zegarra, 2002; Bauer, 2010; Zavalloni et al., 2014; Bauer, 2015
Water trade modeling	Quantitative	Louw and van Schalkwyk, 2001; Turral et al., 2005; Zaman et al., 2009; Alevy et al., 2010; Loch et al., 2011; Wittwer, 2011; Hung et al., 2014; Regnacq et al., 2016; Wheeler et al. 2008a; 2008b; Zuo et al. 2019
Design of water rights	Qualitative and quantitative	Johnson, 1971; Shupe et al., 1989; Michelsen and Young, 1993; Rosegrant and Binswanger, 1994; Ríos and Quiroz, 1995; Matthews, 2004; Solanes and Jouravlev, 2006; Whitford and Clark, 2007; Donohew, 2009; McKenzie, 2009; Raffensperger, 2011; Nordblom et al., 2011; Lefebvre et al., 2012; Jamshidi et al., 2016; Young, 2019
Interstate water governance	Qualitative	Utton, 1985; Rodgers, 1986; Wheeler, 2014

Research topic	Typical approach	Some examples (not exhaustive)
Water use efficiency	Quantitative	Srivastavaa et al., 2009; Manjunatha et al., 2011; Razzaq et al., 2019
Environmental impacts	Quantitative	Tisdell, 2001; Lee et al., 2007; Rambonilaza and Neang, 2019
Climate impacts on water markets	Qualitative and quantitative	Pullen and Colby, 2006; Adler, 2008; Wheeler et al., 2008a and 2008b, 2013; Kahil et al., 2015; Ghosh, 2019; Zuo et al., 2019
Indigenous water rights/markets	Qualitative and quantitative	Nikolakis et al., 2013; von der Porten and de Loë, 2014; Nikolakis and Grafton, 2015; Taylor et al., 2016; Poirier and Schartmueller, 2012
Water quality trade	Qualitative and quantitative	Uchida et al. 2018; Leonard et al., 2019
Informal water markets	Qualitative and quantitative	Brozovic, 2002; Garrick et al., 2019; Munala and Kainz, 2012; Sima et al., 2013; Venkatachalam, 2015; Jaghdani and Brümmer, 2016; Razzaq et al., 2019

Source: Wheeler and Xu (2021, p. 12)

Table A.3 Requirements needed to enable formal water markets

Issues	Questions to guide discussion/thinking
Property Rights/Institutions Legislation Individuals/groups Environment Change/adaptation mechanisms Road to other property rights Unbundled Risk assignment	• Does legislation exist which gives a clear understanding of rights to water for individuals/corporations and other legal entities? If so, is the degree of attenuation clear, and which legislation (or pieces of legislation) are pertinent? • Are the rights separable – or attached to other rights such as land? • Do the rights vary for classes of right holders and or with respect to time (for example, rights that may have been established under different law in time)? If so, what are the differences in the classes of rights? • Are rights transferrable and is there a legislative mechanism for enabling transfer? • Can permanent and temporary trades take place? What is the impact of permanent trades on viability of infrastructure services along parts of the system network? • Is trade only provided for in relation to entitlements, or can trade in derivatives take place? • Can a trade be readily enforced and/or reversed if counterparty defaults? • How are rights enforced and is the enforcement regime effective and efficient? • What are the rules, if any, relating to carryover and other future period transfer of unused portion of allocations in any year? • What rules/constraints attach to trading rights between connected systems? • What rules attach to the technology underpinning the delivery of water to users – such as season delivery rules, channel delivery rules, etc.? • Are the rights able to be qualified in any other way – and if so, on what basis? • What is the risk attached to the characteristics of rights – and when does the risk materialise, and can the risk be transferred with the right? • How are rights presently allocated/weighed between uses – such as urban water corporations and the environment, and what interplay is there with the rights that are privately held? • How do others view the value and risk profile of rights? (e.g. financial institutions/property valuers)

Hydrology
 	
Connected systems
 	
Regulated/Unregulated
 	
Limit and consequences of
 	
breach→environment→end of system
 	
Use, including interception
 	
Do we know what we don't know?
 	
Salinity/water quality considerations
	• Is the hydrology of the system well understood, well documented and monitored and reported on in a way that is supportive of trade?
	• Is there groundwater interaction with surface water systems, and are the interactions well understood, well documented, monitored and reported on?
	• Are the systems modelled and is the impact of a range of future resource scenarios understood by potential market participants and regulators in relation to the system performance (both in terms of economic and environmental use)?
	• Is interception of run-off included in system measurement and management – or is there risk to catchments from growth in "off stream" interception?
	• Have water quality and or environmental considerations the potential to cause the system to fail?
	• Is the interoperability that results from trade tested or modelled?
	• Big picture assessment to bring these two areas together – are the rights articulated in a way that is sympathetic to:
	  • the resource constraint, and
	  • the extent to which the knowledge of the resource is complete.

Issues	Questions to guide discussion/thinking
Externalities and Governance Considerations Institutional Governance Sleeper/dozers Input on average vs 70% rule Known change of use and hydrology inputs Unregulated "use" Metering/Compliance Reversal decisions	• Is the administrative culture and behaviour of those involved in making decisions respected and trusted? • Are there rights in existence that have been inactive, that if traded into a market, may over commit the resource? • How does change of use impact on external environment – energy and road infrastructure, supply chains, labour demand, etc.? Is this a pecuniary externality or a real externality (noting only the latter should be a policy concern) • Does the supplier have the systems, resources and technology to monitor use, and to ensure use is within licenses/entitlements? • Can unregulated use be detected? • Can water use be metered, and enforced, with penalties imposed?
Adjustment Heterogeneity→Gains from trade Societal pressures New knowledge Early-mover advantage Legislation	• Is there a sufficiently diverse (potential) market for water use in the system to facilitate trade (willing buyers and sellers with different use profiles in terms of value add per $ of water), and what is the likely magnitude of these gains (ex-transaction costs)? • Is the political context mature enough to deal with trade – and accepting of the gains from trade as well as the adjustment costs in terms of activity changes that will be involved with trade? • Is there access to the skills, knowledge and finance needed to take advantage of the production possibilities afforded by trade?
Entitlement registers and accounting systems Legislation Plans Registers Early-mover legislation Information availability Allocation announcements Compliance MER Intermediaries	• Has the State made plans for trade in the system, and how far advanced is the planning? • Are enabling resources such as registers available, reliable and trustworthy? • Is information made available on likely market conditions for trade, and is it reliable and trustworthy? • How mature and effective and efficient are the regulatory settings, the institutions and services that support trade (e.g. online platforms) • Are intermediaries able to support the function of the market?
System type Regulated/Unregulated Surface water/Groundwater Connectivity	• Which water sources in the system can be made available for trade? • What is the status of infrastructure and what are the costs of accessing water in the system, and at various parts of the system? • Does trade need to be regulated for system performance and or economic and social interests in different parts of the system, and at whose cost (benefit)? If so, have the rules for trade been identified based on reliable data and articulated to the market and regulators?

Source: Wheeler et al. (2017; pp. 817-819)

GLOBAL COMMISSION on the ECONOMICS OF WATER

The Global Commission on the Economics of Water (GCEW) redefines the way we value and govern water for the common good.

It presents the evidence and the pathways for changes in policy, business approaches and global collaboration to support climate and water justice, sustainability and food-energy-water security.

The Commission is convened by the Government of the Netherlands and facilitated by the Organisation for Economic Co-operation and Development (OECD). It was launched in May 2022 with a two-year mandate.

The GCEW is executed by an independent and diverse group of eminent policy makers and researchers in fields which bring novel perspectives to water economics, aligning the planetary economy with sustainable water-resource management.

Its purpose is to make a significant and ambitious contribution to the global effort to spur change in the way societies govern, use and value water.

E: info@watercommission.org | W: watercommission.org

OECD Environment Directorate
Climate, Biodiversity and Water Division
2, rue André Pascal
75775 Paris Cedex 16
France