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On the Marketisation of Water: Evidence from the Murray-Darling Basin, Australia

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Abstract Policy makers will increasingly have to turn to water demand management in the future to respond to greater water scarcity. Water markets have long been promoted as one of the most efficient ways to reallocate water by economists, but have also been subject to much criticism due to their possible social, economic and environmental impacts. We engage with common critical perceptions of water markets by presenting first-hand evidence of their effects in the Murray-Darling Basin (MDB), Australia. Water markets in the MDB, as developed within an appropriate institutional framework and coupled with comprehensive water planning, have: (1) helped deliver improved environmental outcomes; (2) assisted irrigators' adaptation responses to climate risks, such as drought; (3) increased the gross valued added of farming; and (4) been regulated in ways to meet social goals. If water markets are embedded within fair and effective meta-governance and property right structures, the potential exists for marketisation to increase efficiency, promote fairness in terms of initial water allocations, and to improve environmental outcomes.

Keywords Water markets · Murray-Darling Basin · Economic impacts

1 Introduction

There is growing evidence that the world is facing an unprecedented global water crisis, which signals future dire consequences for economic growth, agricultural production, the environment and the disadvantaged sectors of communities (World Economic Forum 2015). Agricultural water management plays a very important role in addressing the crisis because,

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worldwide, irrigated agriculture accounts for about 70 % of total freshwater withdrawals (Loch et al. 2013). A common view is that unless business as usual changes, water-related problems will get worse over the next several decades (Scheierling et al. 2014).

The standard prescription to meet growing water demand has traditionally been investments in water supply including: major dams, weirs, canals, pumps and other physical infrastructure (World Bank 1993, Sitarz 1993). In many parts of the world the challenge of managing water demand by increasing supply is no longer possible or only possible at much greater cost than in the past. Many freshwater resources are overexploited and, thus, governments at all levels are evaluating ways of managing water demand to signal the scarcity value of water (Scheierling et al. 2014).

In the Rio Declaration and Agenda 21 the international community acknowledged that the era of substantial increases to water supply was coming to an end and that the emphasis in the future would be on managing demand for water, and reallocating water from existing to new users (Sitarz 1993). Since the promulgation of Chile's Water laws in 1981, increased attention has also been paid to water markets and what they can deliver in terms of efficiency and balancing water supply and demand while, in general, water markets are promoted as one of the most efficient means to reallocate water between users (Zetland 2011; Griffin 2006).

A water market is a composite of a variety of water products (temporary or permanent), each situated within a given water system with various boundaries that allows water to be traded from one given place to another, under a range of conditions. Understanding the claims for and against water markets, and what they can actually deliver in practice, is crucial to making better decisions about water use. Here, we document the findings from the actual operations of water markets in one of the world's largest, the Murray-Darling Basin (MDB), Australia. Although our review and analysis is based on a specific location with given institutional and regulatory setting, it is, nevertheless, relevant for other locations in terms of understanding what water markets are able to accomplish.

A 'market fundamentalist' claim of water markets is that they fully respond to scarcity and inherent trade-offs in water use and promote co-operation (Anderson and Leal 2001 p.4). This has led some to suggest that water markets can especially benefit the poor (Thobani 1995) and, as reported by Briscoe et al. (1998), led some within the World Bank to argue that water markets are a panacea to the challenges of water scarcity. By contrast, others contend that water markets which promote trade and commodification only benefit the wealthy and powerful at the expense of vulnerable individuals, communities and the environment (Barlow and Clarke 2002). Neither perspective is properly grounded in the realities of the actual benefits and shortcomings of existing water markets.

We contend there continues to be a misunderstanding of water markets despite more than three decades of experience of research and evidence of what they do and do not deliver. Much of this debate has focused on the provision of water services to urban communities and the 'privatisation' of these services and/or infrastructure, especially in poor countries, with proponents for (Segerfeldt 2005) and against (Goldman 2007). Typically, urban water 'privatisation' does not involve water markets in the sense that water is neither traded among consumers or between those storing or delivering water to urban water consumers. Nevertheless, some of those most vocal against privatisation of urban water equally oppose the establishment of water markets (Barlow 2007).

In our view, and this point was made by Rosegrant and Binswanger (1994) 20 years ago, the time is long past that arguments about water markets be focused on theory and principles, but instead should reflect actual water market experience. We build on the approach such as

Bauer (2004) in Chile and Garrido (2011) in Spain, to use first-hand evidence to review empirically-based outcomes of water markets in the Murray-Darling Basin (MDB), Australia.

Our contribution is to: (1) review the theory versus evidence of water markets; (2) to correct misunderstandings on the effects of water markets in the MDB that are not supported by empirical evidence; (3) provide a synthesis of the most recent findings to show that, contrary to some of the views in the published literature, water markets operating in the context of an overarching institutional framework can be used to deliver better outcomes for the both the irrigation sector and the environment, and respond to social concerns; (4) stress the importance of an effective institutional framework to regulate water markets, to ensure they deliver desired public policy benefits; and (5) highlight where additional water market research needs to be conducted.

2 Effects of Marketisation: Theory Versus Evidence

Bakker (2007) highlights misunderstandings about water markets, and provides a useful framework to explain the competing points of view and distinguishes between institutions (laws, policies and rules), organisations (social entities) and governance (process of decision making). In her framework, she defines the concepts of: privatisation (allocation of individual rights); deregulation (diminishment of the regulatory role of public organisations); decentralisation (transfer of decision making and responsibility to a subsidiary level of authority); corporatisation (shift from public to corporate ownership); commercialisation (adoption of business models of practice and decision making), and marketisation (use of markets to determine use). We add to this list by defining resource commodification as the treatment of natural resources, including water, as a market good (Subramanian 2014).

Bakker's framework helps to distinguish between the arguments for and against water markets. An anti-market view is that they cause appropriative privatisation, whereby state or private actors acquire resources previously held in common and without meaningful compensation. In other words, markets are a tool of global capitalism that results in 'accumulation by appropriation' (Harvey 2003) – the modern day equivalent of 'property is theft!'. Further, according to this view, because the environment is not directly valued by markets it is treated as a residual or simply as an 'externality' and not accorded primary importance (Harvey 1993).

While there may be examples of appropriation through privatisation, these are caused by development impeding institutions (Grafton and Rowlands 1996), rather than well-functioning markets. For markets to play a central role in water appropriation it would require that marketisation be the primary or single cause of the privatisation. Yet there are well-documented examples of privatisation *without* marketisation (Trawick 2003; Bakker 2007). In other words, privatisation that represents exploitation does not need water markets to exist and are attributable to fundamental income, wealth and power inequalities (and the institutions that underlie them) rather than the operation of markets per se.

Additional counter evidence to the anti-market view would be to show that water marketisation is not always accompanied by 'accumulation by appropriation'. Indeed, water markets have been established without 'appropriation by accumulation'. A case in point is the MDB. We stress that we are not saying that water marketisation cannot result in exploitation, but rather that it is not an inherent outcome of markets. In particular, whether appropriation occurs or not crucially depends on the surrounding institutional and social setting.

Water marketisation is synonymous with commodification, but this need not be antithetical to the 'commons', especially if the unique characteristics of water are recognised (Van der Zaag and Savenije, 2006). Indeed, the market can be used as a vehicle to re-establish environmental water which has effectively become private by government fiat through the issue of licences, or simply taking of water from a river system.

Marketisation can result in trades of water at a price that reflects its expected marginal value in use. In other words, water market prices represent the marginal willingness to pay for water in permitted uses by those allowed to buy and sell in the market. Consequently, the marginal willingness to pay for uses of water that are not allowed, and also the values of non-participants values, will not, typically, be incorporated into water market prices. This representation of marketisation has been used (e.g. Kiem 2013) to argue that water markets fail to account for important community, environmental or social values. Thus, according to this view, markets are contrary to the interests of society. In terms of society views on this, in Canada Zuo et al. (2015) found that the younger generation are more likely to be pro-environmental in terms of setting minimum flows in rivers, but less likely to support government intervention and more likely to support markets to reallocate resources.

It has been shown that both community interests and environmental values can, and have been, incorporated into the design of markets. For instance, rights-based allocations to natural resource can be provided to communities, which has been done for disadvantaged communities in the US (Wilson 2014) and Canada (Parsons 1993), among others, to protect collective interests or to rectify past injustices. Contrary to expectations of market sceptics, recent research shows that, provided water rights are made to communities rather than individuals, water markets can receive widespread support in Indigenous communities (Nikolakis et al. 2013). A key to community support, and also fair and just outcomes, is to have stakeholder engagement that establishes a flexible planning process. This planning should evaluate the trade-offs between consumptive and non-consumptive (cultural, social and ecological) use, actively engage all stakeholders in dialogues, support capacity building and community monitoring and review, and ensure initial allocations, permitted uses and trades promote long-term community benefits (Nikolakis and Grafton 2014).

Added protections to reduce the risk of communities being disassociated from their access or use of water can be provided by separating their rights into perpetual shares to a common pool and annual or seasonal water volumes that are based on the perpetual shares. If community water rights are defined in this way communities can benefit from temporary sales or purchases of seasonal water volumes, but can also retain their permanent control over water rights if perpetual water shares are not transferable. Even in the absence of dual water rights (perpetual shares and seasonal allocations), water markets can still be designed to restrict the trade of water rights from and to communities if that is deemed appropriate.

An oft-cited concern is that water markets impose costs on the environment (Kiem et al. 2010, Kiem 2013). It is possible that water trading between different water users can generate worse environmental outcomes. For instance, the direction of trade may result in lower return flows or reduced water quality. Equally possible is for water trade to benefit the environment if the buyers use water in ways that favour the environment compared to its previous use before the trade.

Richter (2014) lists trade in water rights as one of seven principles of sustainable water management; Young (2014) offers six specific institutional design rules for designing water entitlement systems; Livingston (1995) stresses the importance of institutional design if desired social and economic goals are to be achieved by water markets; and Perry (2013) lists

the ABCD + F (accounting, bargaining, codification, delegation and feedback) requirements for effective water resource management. In our view, to ensure environmental goals are met with water markets requires the following basic conditions: (1) a detailed understanding of hydrology conditions and a cap or limit on overall water use that is both effectively monitored and enforced; (2) restraints on trade or the use of trading ratios across different uses and locations, if needed, to ensure that when water is reallocated by trade it does not impinge on key environmental objectives; and (3) effective regulation of water use through licensing arrangements that define user responsibilities and set out rules for how water is used. Obviously, effective regulation of markets is critically determined by property rights and institutional capabilities of countries, hence many countries are unable to effectively implement water markets without these fundamentals in place.

In summary, economic, social and environmental goals are compatible with water markets, but this demands appropriate property rights, hydrological information, market rules and design. To achieve these objectives requires: (1) market regulation and oversight based on transparent and measurable goals (Honey-Rosés 2009); (2) the integrated involvement of the market sector, governments and civic society (Richter 2014) and (3) an appropriate meta-governance structure (Bell and Quiggin 2008) that bridges institutional and landscape scales. Effective water resource management is also impossible without a concerted multi-disciplinary effort involving hydrologists, engineers, economists, lawyers, planners, scientists, agronomists, environmentalists and climatologists (Perry 2013).

3 Water Trading in the MDB: Buyers, Sellers and Constraints on Trade

A key concern of marketisation sceptics is that trade will move water from current, low value uses to higher value alternatives with unintended and negative social or environmental consequences. For instance, some farming communities in the US have raised concerns over the transfer of large volumes of water to urban centres (Ingram and Oggins 1992). Such long-held concerns have resulted in water laws that make transfers across sectors more difficult than within agriculture (Burness and Quirk 1979). In the MDB, Kiem (2013) asserts that markets will end up reallocating water from 'low-value' uses such as agriculture to 'high-value' uses such as mining, manufacturing and electricity production. This is presented as undesirable. We critically assess this assertion based on actual evidence of past water trades in the MDB.

The principal buyers and sellers of water rights in the MDB are irrigators and who collectively consume about 70 % of the water diverted in the Basin for non-environmental uses, from about 2 % of the surface area. The main irrigation uses include: (1) perennial agriculture such as for orchards, vines and trees; (2) annual agriculture with the primary water uses for rice and cotton and (3) milk production based on watered pasture for dairy cattle. How much volumes of water each of these enterprises buy or sell in an irrigation season depends on rainfall and water allocations which, in turn, are based on current levels of storage in the major dams in the MDB and expected inflows, and water carried over previously. At low water allocation prices dairy farmers will generally use their own water allocations to grow pasture, but as prices rise (>AUD$220/ML) it becomes more profitable for them to either purchase supplemental feed or 'dry out' their cows and sell their available water. Rice and cotton growers will produce at low to moderate water prices, but at higher prices (>AUD$465/ML) it is no longer economically viable to grow these crops and it is more advantageous to sell water. The perennial agriculturalists are able to pay the most for

water in terms of their farming operations as they require a minimum amount of water that cannot be reduced if they want to ensure their trees or vines viability. Thus, perennial agriculturalists will, in general, only sell water if prices go above AUD$640/ML (Wheeler et al. 2014b).

The roles of different MDB stakeholders can be summarised by noting that the federal government's responsibilities are to set, monitor and enforce the overall water market rules and annual monitoring, evaluation and enforcement of the Basin Plan enacted in 2012; undertake, with the assistance of the States, Basin-wide planning and accredit state regional water plans; determine the average sustainable diversion limits in each catchment within the Basin as part of an overall Basin Plan; determine the appropriate allocations for the environment based on its own water entitlement holdings; and execute a Basin environmental watering strategy (Hart 2015). The states have responsibility for their own water plans in their own jurisdictions provided they are consistent with the Basin Plan; determine the allocations to their state water entitlements subject to sustainable diversion limits; determine their own environmental flows separate from any releases by the Commonwealth Environmental Water Holder relating to their planned and held environmental water; and meet their inter-state and federal obligations regarding flow regimes. The irrigators are the holders of water entitlements that are statutory rights, as permitted by the States, and are also the primary users of the surface and groundwater in the Basin.

To date, two types of market transactions have dominated water trading in the MDB. These are trading with irrigators on both ends of the transaction, and trading between an irrigator and a government body, standing as proxy for the environment. The trades consist of the buying and selling of two types of water rights, both of which are statutory rights, namely: (1) water allocations or physical volumes of water allocated each irrigation season to holders of water entitlements and (2) water entitlements - the underlying right to an on-going share of a consumptive pool in a water resource plan and which can vary in terms of reliability or the proportion of the time an entitlement receives its nominal allocation (Grafton and Horne 2014). Within state trading of water allocations has been allowed since 1983 in New South Wales (NSW) and South Australia (SA), and since 1987 in Victoria, while water entitlements have been permitted to trade since 1983 (SA), 1989 (NSW and Queensland) and 1991 (Victoria). In 1995, inter-district (state) trading was allowed. In addition, water use is regulated by state water use licences, and other institutional arrangements, that impose rights and obligations covering, for example, how water is used in a specific locality, and delivery shares that represent a capacity share of an irrigation supply channel (Wheeler et al. 2014a). Trade in water allocations has grown by several multiples since the introduction of a 'cap' on surface water use and the agreement to 'unbundle' surface water rights from land by the Council of Australian Governments (COAG 1994) in 1994 (Grafton et al. 2012).

Despite the fact that the water allocation markets have been well established for 20 years, the indirect evidence is that there have only been small volumes of trade from irrigators to mining or manufacturing or electricity production. The ABS Water Account of Australia (2013) shows that agriculture consumed 59 % of all of Australia's water consumption in 2011–12, followed by the water supply and sewerage services industry (13 % of the total consumption), households (11 %), mining (4 %), manufacturing (3 %) and electricity and gas supply (3 %). Mining, manufacturing and electricity users have not significantly changed their water consumption share from 2008-09 onwards.

In the case of water entitlements, the only substantial sales other than between irrigators, have been trades to governments, especially the federal Australian government with the intent

to increase environmental flows. Between 2008- and the end of 2012 the Australian government purchased from around 4500 willing sellers, in a series of reverse auctions, a long-term equivalent volume of surface water entitlements equal to about 10 % of long-term average surface water extractions in the MDB (Wheeler and Cheesman 2013). In terms of the farm impacts from selling water, Wheeler and Cheesman (2013) found that 50 % of farmers said selling water entitlements had no impact on their farm production; and 80 % in hindsight were happy with the decision they made to sell water, and would not change it.

The Australian Competition and Consumer Commission has rules that prevent restrictions on trade by individual market participants that came into force on 1 July 2014. In the past, state governments have determined how rights are allocated or traded and could prevent trades they did not wish to occur. For instance, the NSW government has a 10-year 3 % trade cap on water entitlements out of each basin valley if purchased for environmental purchases. In 2011 Victoria also established rules that, to date, have resulted in no transfer of water along an AUD$750 million north-south pipeline that was built for the expressed purpose to provide an additional source of drinking water for Melbourne.

In summary, water markets in the MDB have not resulted in the transfer of any substantial volumes of water from irrigators to non-farming 'high value' purposes, except to increase environmental flows. Nevertheless, state governments have the legal authority, and have a shown a willingness to exercise their rights, to prevent water trades from irrigation to what they would consider to be undesirable purposes, including urban water use and environmental flows. As with any good, trade should be subject to a public interest test, but the reasons for constraints on trade should be transparent along with the desired goal from any restrictions and an assessment of the costs and benefits of such restrictions (Grafton and Horne 2014).

4 Climate Risks and Economic Impacts of Water Trade

Climate risks in the MDB are primarily drought-related although there are occasionally large flooding events that pose costs to farmers, households and businesses on the Basin's flood plains. Drought-related risks are, typically, managed through water storages, which in total can store the equivalent of about two years of annual extractions. As inflows and storage levels fall, state governments will reduce water allocations to water entitlements and also the 'planned' environmental water releases. During the most recent Basin drought, allocations for environmental flows were cut, on average, four times as much as the allocations to water entitlements to irrigators (Grafton et al. 2013). While irrigators have historically been given higher priority to water than the environment in relation to this rules based or 'planned' environmental water, the highest priority water users are riparian communities in the Basin who are reliant on water for drinking purposes, and water extracted and directly used for 'stock and domestic' purposes. In sum, the greatest climate risks are borne by the environment; followed by water entitlement holders with low and then general levels of reliability and then water entitlement holders with the highest levels of reliability; then directly extracted stock and domestic uses of water with the highest priority accorded to urban drinking supplies. The purchase of entitlements for environmental use by the federal government in particular (known as 'held environmental water') has reduced water planning risks to environmental flows because these entitlements share the same rights as those held by irrigators.

Two commonly cited concerns of water market sceptics (e.g. Kiem 2013) are that: (1) water transfers, especially across competing uses and between catchments, can impose substantial social and economic spill-over costs to persons and communities not directly involved in the transactions; and (2) there may be 'appropriation' that can arise when inexperienced and/or unwitting sellers or buyers sell or buy water rights at below or above the 'fair' market price and/or who fail to consider the full economic implications or risks to themselves as a result of their sales or purchases.

Common concerns raised about water entitlement trade include the reduction in local spending and employment prospects, and a decline in public services should water be permanently traded out of a region (Kiem 2013).

However, there has been considerable research on the economic and social impacts of water trade in Australia (e.g. NWC 2012; 2010; Wheeler and Cheesman 2013; Wheeler et al. 2013, 2014a). Detailed economic studies of the effects of water entitlement trade have also been conducted in the MDB with the most comprehensive undertaken by NWC (2012). It showed that over the period 2006–07 to 2010–11 water trade increased the regional domestic product of the MDB by some AUD$4.3 billion while in the driest year of the drought, in 2007–08, the total benefits were some AUD$1.5 billion. Harris (2011) stated that institutional path dependence has caused restrictions in Victorian water markets, which while not necessarily permanent; in the short-run has limited water trading gains.

Using actual farming data rather than model outputs, Kirby et al. (2014) found that despite a more than 70 % decline in irrigated surface water from 2000 to 01 to 2007–2008 as a result of much reduced inflows, the adjusted gross value of irrigated production fell by just 10 %. This remarkable adjustment by irrigators was the result of several strategies including changing crop mixes, improving irrigation efficiency and trading water. It also provides strong evidence of a positive role of water markets for individuals and their communities.

The potential benefits of water markets to assist in adaptation does not imply there should not be publicly-funded adjustments to help communities in times of stress for social reasons (Alston and Whittenbury 2011). Such community-focussed support measures should complement rather than substitute for individual farmer actions. In addition, bottom-up and community-based approaches are possible such as 'system harmonisation', which involves irrigators and communities working together in the MDB to solve catchment scale problems.

Based on responses to the largest survey of water entitlement sellers conducted in the MDB, many sellers remain in their local area after selling their water entitlements (Wheeler and Cheesman 2013). This same study found that 60 % of sellers in irrigation areas kept their water delivery shares. Retention of delivery shares provides counter evidence to the concern that water entitlement trade will result in unused or 'stranded' irrigation assets.

Markets for any good or service can impose costs on either buyers or sellers if they pay more or sell the asset at a price that exceeds or is less than its value to the asset holder or the market price. The public policy question about water markets is whether there is market power or asymmetric information that favours one group of buyers or sellers over another, or if the market price of the asset differs fundamentally from its 'fair market' value.

Grafton and Horne (2014) found that MDB water markets are competitive and do reflect underlying market fundamentals. For instance, they show how average water allocation prices have varied within season and across years from 2007 to 08 to 2011–2012 as a result of changes in water availability. Wheeler and Cheesman (2013) found that the majority of irrigators who sold water entitlements to the government did so because they believed they received a higher price than would otherwise have been the case.

An important issue is to what extent water trading has helped or hindered farm profitability and risk mitigation. Based on 3248 unit-level MDB farm records over the period 2006–07 to 2010–11, Wheeler et al. (2014b) found that selling a larger volume of water allocations improved farm viability, and that there was no significant impact in the farm's current financial year from selling water entitlements. Further, Wheeler et al. (2014c) found there was no significant delayed impact from selling water entitlements on farms that stayed farming. Finally, Zuo et al. (2014) further find that farmers experiencing higher variability in profit and facing more downside risk purchased greater volumes of water allocations in general. Purchasing water allocations on the market was, therefore, a risk-reducing strategy, especially for horticultural farmers. Exploring this in more detail, Nauges et al. (forthcoming) found that horticultural irrigators used water allocation trading because they are averse to the risk of large losses (downside risk) while broadacre irrigators use water trading as they are averse to the variability (variance) of profit. Water trading, therefore, has provided a risk-management strategy for these irrigators.

Based on thousands of survey responses in the MDB, it has been shown that irrigators have become more favourably disposed to water trading from the 1990s to 2010. Empirical evidence details that irrigators and communities in the MDB have been very accepting of water allocation trading, but more reticent about water entitlement trade (Bjornlund et al. 2011). While acknowledging the possible negative community impacts of entitlement sales, irrigators consistently recognise the beneficial impacts of water trading on their farm businesses. The positive effects of water trading are also supported by market data on trades which show that by 2010–11: 86, 77 and 63 % of irrigators, respectively, in NSW, Victoria and SA had undertaken at least one water allocation or water entitlement trade (Wheeler et al. 2014a).

In summary, the decade-long Millennium Drought that ended around 2011imposed large adaptation costs on irrigators and rural Basin communities (NWC 2012). The cause was most certainly not water markets, but rather record low water inflows. Indeed, the economic costs caused by low inflows during this drought were substantially mitigated by water trading because, by buying and selling water, farmers were able to improve their economic viability. In sum, the vast majority of irrigators in the MDB have chosen to trade (buy or sell) water allocations or water entitlements, and most irrigators state that water trading has been beneficial to their farm businesses.

5 Water Policy, Water Trading and Environmental Flows

As defined in the *Water Act 2007* (Section 3, paragraph (d)) the Australian government's 2012 Basin Plan is intended to: (1) "…ensure the return to environmentally sustainable levels of extraction for water resources that are overallocated or overused" and to "…protect, restore and provide for the ecological values and ecosystem services of the Murray-Darling Basin" (Australian Government 2014 p.2).

In response to perceived environmental costs during the Millennium Drought, the Australian government sought to acquire water by subsidising on and off-farm water use efficiency, and also by purchasing water entitlements from willing sellers. The cost of acquiring a volume of water for the environment via infrastructure subsidies is about four times more expensive than purchasing water entitlements (Productivity Commission 2010). Thus, for a given budget, the most cost effective way to increase environmental flows by the Australian government is to purchase water entitlements (Grafton 2010; Horne 2014). There are also benefits from the use of water allocation trade (Connor et al. 2013).

A key risk associated with irrigation subsidies as an instrument of water policy, which does not arise from the purchase of water entitlements, is that they can reduce return flows that may have a negative impact on environmental flows downstream. Infrastructure subsidies appear to be increasing over the decades and have increased in-stream salinity (Harris 2011). Subsidies may also encourage irrigators to expand their irrigated cropping area and shift towards higher rates of perennial crop production (Adamson and Loch 2014) and, thus, could substantially raise allocation prices during a drought (Grafton et al. 2014).

Projected climate change will exacerbate environmental impacts in the MDB and other mid-latitude rivers (Colorado, Orange and Yellow Rivers). Nevertheless, it is the currently high levels of water extractions that are the primary causes of reduced system slows (Grafton et al. 2013; Horne 2013) and that have contributed to an over 60 % reduction in mean end-of-system flows in the MDB relative to what the flows would have been without irrigation (Grafton et al. 2014). To the extent that the purchase of water entitlements by governments to increase environmental flows is the most cost effective means of reducing over extraction, water markets provide an effective means to respond to existing environmental concerns around system flows. Not only are water purchases by governments effective at reducing water extractions, it appears that during the Millennium Drought that the marginal water used in the environment generated a higher economic value than in irrigation (Grafton et al. 2011).

An important issue connected with water trade between irrigators is the effects of such trade on environmental flows. During the Millennium Drought the direction of trade was downstream with trade contributing to increased end-of system flows in the Murray River and key tributaries including the Murrumbidgee, Goulburn and Loddon Rivers (National Water Commission 2010). Consequently, the NWC (2012) found that the environmental impacts from water trade between 1998 and 99 and 2010–11 were small and largely positive; due to the downstream movement of water during the drought and reduced summer flow stress.

Negative environmental impacts occur when trade results in a detrimental change to the volume, location and/or timing of water use. NWC (2012) found that water trade had reduced flow stress in river systems, particularly with regard to natural flow variability and better flow patterns in summer months. Thus, water markets helped to mitigate the effects of drought on the environment and were consistent with the objectives of water policy of the Australian government.

Critics such as Alston and Whittenbury (2011), Kiem (2013) and others argue that the social, economic, and environmental costs of water trading are poorly understood, making water markets a poor adaptation tool. But, actual evidence from the MDB shows that water markets have: (1) increased end-of-system flows during the Millennium Drought; (2) provided a key adaptation tool to irrigators to restructure and survive water scarcity; and (3) provided a cost effective option to governments to reduce over extractions of surface water within the MDB. Nevertheless, there remain water governance issues that need attention, such as: reducing unnecessary barriers to inter-regional trade in the market; developing new water market products (e.g. forward contracts, options and water donations, urban water markets); improving weather and water market information (e.g. water price, climate, commodity forecasts and allocation information); investigating complementary market-based instruments (e.g. carbon credits), and evaluating key hydrological issues (e.g. the relationship between irrigation infrastructure investment and reflows, and between increased groundwater use and surface water trade) (Wheeler 2014).

Notwithstanding the evidence in support of water trading to help mitigate climate risks for irrigators; increase net returns of farmers; and support environmental objectives, there remain state and federal political risks to achieving these benefits. First, trading restrictions have in the

past, and could again, be imposed by states in support vested interests that will diminish the gains from trade. However, states will need to contend with the considerable powers of the water-trading regulator, the Australian Competition and Consumer Commission. Second, most of the catchments in the MDB still have water sharing plans that give a priority to agriculture over the environment as water storages decline and which was a major factor contributing in very large degradation at the Mouth and lower reaches of the Murray-Darling during the last drought. As these plans are renewed or new plans made they will need to be amended before accreditation by the MDBA, which should reduce this potential risk. Third, even in the absence of 'surprises', the permitted sustainable diversion limits under the Basin Plan for both surface and groundwater may be insufficient to meet the objectives of the *Water Act* and the Basin Plan. This can be reconsidered when the plan is revised in the early 2020s but in the meantime it remains a heightened risk as climate change impacts were not an explicit element factored into reduced sustainable diversion limits. Fourth, on-going subsidies to irrigators to improve water-use efficiency poses risks in terms of reduced and unaccounted for return flows if the accounting is not carefully done, as well as possible 'lock in' with its apparent favouring of perennial over annual cropping systems. Fifth, inadequate funding for on-going monitoring of the effects of the Basin Plan, especially in terms of watering and environmental outcomes, if it were to eventuate, may compromise the quality of future decision making. Sixth, conflicting objectives and approaches by Australian states still limit the potential for a whole-of-basin approach to management. And finally, seventh, a well-functioning and competitive water market requires reliable and up-to-date information, which may be compromised if funding for this activity and other activities administered by the Bureau of Meteorology diminishes.

6 Conclusion

Projected large increases in future global water demand means that there needs to be a greater adoption of water demand management. Water markets have been promoted for many years by economists as representing an efficient and effective means to reallocate water. Common critiques of water marketisation are that it has penalised the poor or disadvantaged, degraded the environment, diminished 'social flows' and has been ineffective at promoting adaptation to climate change and variability. But, direct surveys of farmers and recent evidence on irrigator and environmental outcomes in the Murray-Darling Basin supports an alternative and empirically-based set of conclusions about water markets.

First, water markets are widely used by irrigators in the Basin and are recognised by many as being beneficial to their farm businesses. Second, water markets are competitive and are responsive to changes in water availability such that they represent the underlying value of water in irrigation. Third, water trading during the Millennium Drought substantially mitigated the costs to farmers and their communities of greatly reduced water availability. Fourth, the most cost effective means of reducing over-extraction in the MDB, and a key goal of water policy of Australian governments, is through the voluntary sale of water entitlements from irrigators to governments via reverse tenders. Fifth, water trading during the Millennium Drought increased end-of-system flows in key rivers within the Basin and, thus, provided valuable environmental and economic benefits. Sixth, water trading has provided a key market-based adaptation strategy for farmers in the MDB and a means to respond to likely increases in future water variability.

The overall net benefits from water markets in the MDB may not apply elsewhere. Indeed, there is a need for an 'emerging water market' framework that would provide practical and evidence-based advice for practitioners to consider the benefits and costs associated with implementing water markets, and the institutional conditions required.

Nevertheless, the fact that water markets coupled with effective water planning and regulation have made an important positive contribution to economic, environmental and social outcomes in the MDB indicates their potential to deliver positive outcomes. The achievements of MDB water markets show that marketisation can be designed to increase efficiency, maintain equity and fairness over access and use, and improve environmental outcomes.

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