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The role of the commonwealth environmental water holder in annual water allocation markets*

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In recent years, the Government of Australia has bought back a significant amount of water entitlements in the Murray-Darling Basin (MDB) through its Commonwealth Environmental Water Holder (CEWH) agency. This has been a welcome development, as it is an efficient way of securing water for the environment in the basin. However, the question of how to best manage water holdings held by the government is as yet unresolved. In particular, the question of whether and how should the CEWH engage in water markets is still grappling the government and academia alike. This paper addresses that question by evaluating total benefits to a range of water users, including the environment, under a variety of hydro-climatic conditions. This is approached through running simulations based on environmental benefit function that varies with prevailing hydro-climatic conditions. The findings indicate that the benefits are greater when CEWH actively participates in annual water allocation market and that such participation enables the CEWH to secure most water when it is needed the most by the environment. This suggests that policy should encourage the CEWH to further explore opportunities to engage with the water markets to the benefit of communities and the environment in the MDB.

Key words: benefit functions, environmental water, water market.

1. Introduction

The Murray-Darling Basin (MDB) is one of the largest river basins in the world and a home to an extensive and successful irrigation industry. The over extraction of water for irrigation and other purposes in the basin has been well documented (eg. Randall 1981; Quiggin 2001) and has been addressed by numerous policies over the last twenty or so years (Lee and Ancev 2009). Perhaps to small credit to the economics profession that has argued for policies focusing on reclaiming the extractive water rights through market mechanisms, the Australian government has instituted the so called ‘buyback’ program, where water entitlements are bought from willing sellers by a government agency and are held for the purpose of environmental management. Water entitlements are tradable notional rights to use a given volumetric quantity of

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water that are valid in perpetuity. Every year, irrigation season, or at other time intervals, announcement is made by relevant authority as to the allocation of actual water for that period. These tradable allocations are expressed as a percentage of the entitlements.

The Commonwealth Environmental Water Holder (CEWH) has been constituted based on the Australian Commonwealth legislation known as the Water Act 2007. Under the Act, the CEWH's main task is 'to manage the Commonwealth's environmental water to protect and restore the environmental assets of the Murray-Darling Basin,...' (Commonwealth of Australia 2012; Part 6, Division 1). The main activity of the CEWH since its formation has been acquiring existing water entitlements from their original holders. These entitlements are to be managed so that increased flows are provided to rivers and wetlands, with an ultimate aim to improve their environmental/ ecological condition. Whereas this general aim is noncontentious, the nuances of how exactly to translate acquired entitlements into environmental outcomes are not at all straight forward (Crase *et al.* 2011). This is accentuated by the fact that entitlements held by the CEWH inherit their reliability, that is, they are subject to the same process of annual allocation announcements depending on the type of the entitlement. High security entitlements typically get close to 100 per cent allocation in most years, whereas allocations to general security entitlements vary substantially over time and space (catchments), and can be as low as zero in times of drought. Entitlements held by CEWH are also subject to carryover rules in the systems to which they pertain. Those rules also vary significantly across catchments: for example, in 2013, entitlements in NSW Murray could carryover 50 per cent of unused allocations; in Victorian Murray they could carryover 100 per cent; and in Murrumbidgee they could carryover 30 per cent of unused allocations.

At present (mid 2013), CEWH holds entitlements to about 1630 gigalitres (GL) of surface water, which represents about 13.5 per cent of all surface water withdrawal entitlements in the MDB. Of these, about 560 GL are high security entitlements, 850 GL are general security, and about 200 GL are supplementary, unsupplemented and unregulated entitlements [Commonwealth Environmental Water Office (CEWO) 2013]. How to best use these entitlements from environmental, economic, and social perspective, and whether and how to participate in the water market have been issues that the CEWH has grappled with. The CEWH released a discussion paper on its trading arrangements, where the circumstances under which trade can be effectuated are outlined and discussed (CEWO 2011). In summary, the circumstances when water trade can be considered as an option, as described in that discussion paper, appear to be fairly restrictive.

Given the discussions about how best to use the entitlements currently held by the CEWH, and what should the role of CEWH in allocation water market be, the present paper pursues the following questions: (a) should the CEWH actively participate in the market for annual water allocations, by selling allocations to its entitlements, but also by buying allocations from other entitlement holders?; and (b) what is the likely pattern of trade (buying/selling) that is going to deliver largest overall benefit to society, keeping in mind that the needs for environmental water flows in the basin are likely to vary substantially over time dependent on particular hydro-climatic conditions?

These questions are pursued by conducting simulations of a water market under alternative hydro-climatic conditions. The simulations incorporate benefit functions for the extractive uses of water, as well as benefit functions for environmental uses. The latter are approximated by the expected environmental benefits as a function of annual allocations, which vary dependent on the prevailing current and preceding hydro-climatic conditions. The main premise of this study is that a certain quantum of environmental water flows is likely to yield significantly different benefits in different periods (years) dependent on the overall conditions in the basin.

The reminder of the paper is organised as follows: section two overviews previously published work, followed by the conceptual framework in section three; section four provides details on the research approach and data, followed by section five that presents the findings from empirical simulations; section six draws conclusions and examines policy implications.

2. Previous literature

Since the early 1980s, water trade in the Murray-Darling Basin has been slowly gaining momentum. The volume of water trade has increased substantially in recent years in response to reduced inflows and low seasonal allocations (Grafton 2010). Trade in water entitlements and water allocations in the basin generates substantial economic benefits to individual irrigators and to their farming communities (Peterson *et al*. 2004). In recent years, the Australian Government's 'Water for the Future' initiative has created an opportunity to acquire water entitlements under the buyback program. Several authors, including Tisdell (2010), Grafton (2010), Crase *et al*. (2011), Loch *et al*. (2012), Qureshi *et al*. (2007) and Ancev and Vervoort (2008), have explored the possibility to trade in environmental water. Other studies (eg. Hone *et al*. 2010; Productivity Commission 2010; National Water Commission 2011) investigated the impact of environmental water trade, in particular the effect of water buybacks on the water market.

Recent studies (eg. Leroux and Crase 2010; Wheeler *et al*. 2011) found that the environmental water holder might benefit from trading in seasonal allocations and in derivative water products. While the literature has identified a range of significant positive and negative impacts of environmental water trade, focus has been placed on the possibility that environmental water holder could have a significant sway in the market by being able to buy large volumes of water allocations in short periods of time and by being able to carryover seasonal allocations (Loch *et al*. 2012).

Besides this fairly rich recent literature, the full range of the expected effects from CEWH taking a more active role in the existing water market are not yet fully understood. The present study aims to fill this gap by investigating the overall benefits of environmental water trade from a perspective of water extractive sectors and from the perspective of environmental water needs. This aim is pursued by examining a series of simulation scenarios conducted under a range of possible hydro-climatic conditions.

3. Conceptual framework

The simulation scenarios investigated in the ensuing empirical analysis are based on a standard conceptual framework relevant to water markets. The key premise is that society's well-being from using surface water – groundwater is not considered here as it is subject to different governing rules and has different environmental significance – is maximised when water is optimally allocated among water users and the environment.

Suppose that there are two types of entitlements held by extractive water users: general security, comprised of irrigators of relatively low value irrigated crops; and high security, comprised of irrigators of high value crops and municipal and industrial water users. The environment is a nonextractive water user. In this case, society's problem in a given period can be represented by

$$\max_{w_{\text{in}}} \sum_{i} \sum_{n} B_{\text{in}}(w_{\text{in}})$$

$$\text{subject to} \tag{1}$$

$$w_{\text{in}} \leq a_{\text{in}} ew_{\text{in}} + bw_{\text{in}} - sw_{\text{in}}$$

where w_{in} denotes water used, and $i = g$ (for general water security); h (for high water security), and $n = v$ (for environmental water); z (for water in extractive uses). B_{in} denotes the benefit function from using water in a particular activity. For water in extractive uses, the benefit function can be approximated by the value-added attributable to water in irrigated agricultural enterprises or in industrial or municipal enterprises. For environmental water, the benefit function is more difficult to articulate, as it inherently reflects society's preferences for water in rivers and streams being dedicated to support environmental and ecological functions. Benefit functions are discussed in more detail in Section 4 below.

The institutional setting for water use is based on current characteristics of the surface water governance rules in Australia. Each type of water user, environmental and extractive, holds water rights. These rights are called entitlements, ew_{in} in Equation (1). Every year, or irrigation period, an announcement by the authorities is made about allocation of actual water to each type of entitlement as some proportion of it, denoted by a_{in} in Equation (1). The magnitude of the announced allocation that can be expected by an entitlement holder is the main difference between high security and general security water rights: high security entitlements tend to have high allocations (a_{in} is often close to unity), whereas general security entitlements tend to have lower allocations, sometimes as low as zero. Environmental water entitlements carry the security characteristics of the original entitlements that were purchased through the 'buyback' program.

The model in Equation (1) assumes frictionless water trade, where only allocations announced for that period are traded among water users: water entitlements (permanent water rights) are not traded in this model, as the primary interest of this study is the trade of allocations (temporary water rights), and hence the static nature of the model. In Equation (1), water allocations bought by a water user are denoted by bw_{in}, and water allocations sold are denoted by sw_{in}. Trade in water must satisfy the following: $\sum_i \sum_n bw_{\text{in}} = \sum_i \sum_n sw_{\text{in}}$

Given the structure of the model, the objective is to distribute annual water allocations across water users, so that the sum of benefits for all water users is maximised. The Lagrangian function for the optimisation problem in Equation (1) is:

$$\sum_i \sum_n B_{\text{in}}(w_{\text{in}}) + \lambda(a_{\text{in}} ew_{\text{in}} + bw_{\text{in}} - sw_{\text{in}} - w_{\text{in}}) \tag{2}$$

Given the nonnegativity of water allocated to any use $w_{\text{in}} > 0$, the associated Kuhn–Tucker conditions for optimality are:

$$\begin{aligned} &\frac{\partial B_{\text{in}}}{\partial w_{\text{in}}} - \lambda \leq 0; w_{\text{in}} \geq 0; \left[\frac{\partial B_{\text{in}}}{\partial w_{\text{in}}} - \lambda\right] w_{\text{in}} = 0; \\ &a_{\text{in}} ew_{\text{in}} + bw_{\text{in}} - sw_{\text{in}} - w_{\text{in}} \geq 0; \lambda \geq 0; [a_{\text{in}} ew_{\text{in}} + bw_{\text{in}} - sw_{\text{in}} - w_{\text{in}}]\lambda = 0 \end{aligned} \tag{3}$$

implying that in equilibrium, marginal benefits of using water are equalised among water users.

4. Research approach and data

The postulated research questions were pursued by conducting simulations based on the conceptual framework described above. Simulations were run for various levels of announced allocations, effectively representing various 'water periods' or years. For each scenario, there were ten periods simulated. For each period, a static optimisation based on the model presented in Equations (1–3) was run. In scenarios where benefits from environmental water varied over time depending on the current and preceding hydro-climatic conditions, the environmental benefit function applicable to a particular period was assigned according to the observed hydro-climatic conditions. Consequently, sequences of ten periods within a simulation scenario were dynamically related via the effect of current hydro-climatic conditions on the next period conditions and thereby on the applicable environmental benefit function. For example, if current period is ‘dry’, and the previous period was also ‘dry’, the present hydro-climatic condition was termed very dry (Year Type 2), and the corresponding benefit function was used.

Carryover of unused allocations explicitly takes precedence over trading in the current water trading guidelines for the CEWH (CEWO 2011, p3): ‘...Disposal of allocations and/or entitlements may occur if: these are not required to meet environmental objectives in a given water accounting period and cannot be carried over to the next accounting period...’. There is little evidence that can support such precedence when active markets in annual water allocations exist. Insisting that water be kept for next season rather than traded implies that market participation is seen as inferior to autarky. In addition, carryover varies widely between regulated river systems, and in some systems, carrying over unused allocations implies significant transactions costs (eg. 5 per cent evaporation losses, and sometimes up to 70 per cent carryover discount, as in Murrumbidgee in 2013). For these reasons, and given that the present paper is interested in annual water allocation market, carryover was not explicitly treated in the simulations.

Simulation scenarios were based on the following five criteria: (1) whether the CEWH participates or not in annual water allocations trade; (2) whether benefits from environmental water are fixed across all years of the simulation, or they vary dependent on current and preceding hydro-climatic conditions for a given year; (3) whether the expected annual allocations are high or low compared to a long term average; (4) whether the variability of annual allocations within a 10-year period is high or low compared to a long term average; and (5) whether periods with wet or very wet hydro-climatic conditions are clustered together or spread out within a 10-year simulation period. The significance of these criteria and the data used to describe them are discussed below.

Regarding criterion (1), there is limited interest in simulations when CEWH does not participate in annual water allocation trade, and those simulations are used as base case for comparison with simulations that involve CEWH participating in water trade. Criterion (2) encapsulates the benefit function for each water user. An aggregate benefit function was estimated to reflect the monetary value of benefits from water use to a particular user as a function of volume of water allocated to that use. The benefit function for high security entitlements in extractive uses represents the aggregate benefit to this diverse group of water holders derived from using water. For industrial users and irrigators of horticultural crops, this is determined by the value of water in their production, whereas for municipal users, the benefits can be determined by the demand for water from urban water users (Figure 1). The benefit of allocating water to general security entitlements in extractive uses is the value of produced irrigated crops net of cost of their production and the opportunity cost of land (Figure 1). Benefit functions for these two types of water users were estimated based on data collected for the Namoi catchment as reported in Lee (2007), and Lee *et al.* (2007, 2012).

A key premise around environmental benefit functions in the current study is that benefits from environmental water are dependent on the amount of ecological benefits that can be attributed to certain levels of water flows at certain times. In particular, recent publications suggest that ecological benefits are highest in wet years that follow a spell of dry years, when inundation of the flood plains ensures that water-dependent ecosystems are reinvigorated (Heaney and Beare 2012; MDBA 2012). Conversely, benefits from additional environmental water in dry years that follow a spell of wet years are relatively modest, because adding a marginal volume of flow to an already diminished river or stream does not add much ecological benefit and because the Australian river systems are naturally well-adapted to wet and dry cycles (Puckridge *et al.* 2000; Thoms and Sheldon 2000). This means that after a wet period, the ecosystem can be resilient to several dry years before the next flood is needed.

This premise is consistent with the recently published ‘Guidelines for the method to determine priorities for applying environmental water’ [Murray Darling Basin Authority (MDBA) 2012]. The guidelines specify current and preceding hydro-climatic conditions to determine the state of water resources

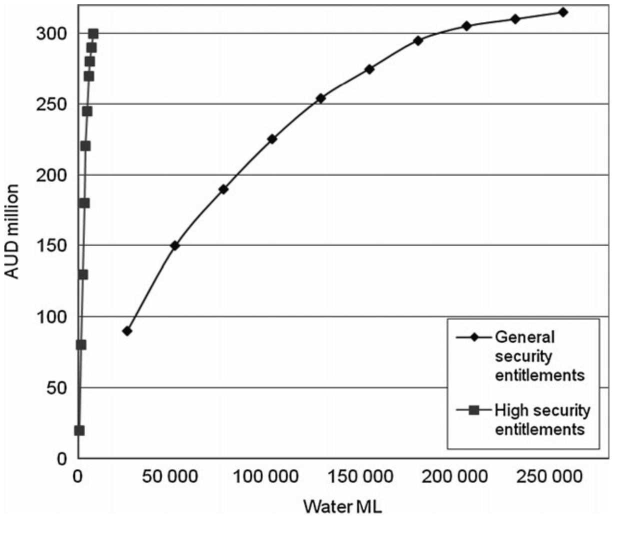

Figure 1 Benefit functions for water allocated to high and general security entitlements in extractive uses.

– called resource availability scenarios (RSA) – in the basin. For example, if current surface water availability is between the 0 and 15 percentiles, and the preceding availability was between the 0 and 45 percentiles, the state in the basin is termed 'very dry'. Likewise, if current availability is between the 46 and 60 percentiles, and previous availability was between the 61 and 100 percentiles the state in the basin is termed 'wet'. There are total of five possible states identified that the basin can be in: 'very dry', 'dry', 'moderate', 'wet' and 'very wet'. These states of the basin are then linked to environmental management outcomes, which stipulate the objectives of management in each state. The wording associated with dry states includes terms like 'maintain' and 'support', whereas wording corresponding with wetter states includes terms like 'improve' and 'promote'.

Stipulations published in the 'Guidelines…' justify the thinking that there is not much point in directing a lot of environmental water in dry times. When times are tough, the environmental objectives are ones of survival, which could be supported with relatively little water. Water-dependent ecosystems in the basin are quite resilient, and can sustain dry conditions on very little 'life support' for some time, but not forever. That is why it is important to provide as much environmental water as possible in wetter years. That way, the ecosystems can recover from dry periods and can build up the resilience to sustain dry periods in the future.

Based on these arguments, five types of benefit functions for environmental water, roughly coinciding with the five possible states of the basin described in the 'Guidelines …' (MDBA 2012) were empirically determined based on environmental and ecological data published in various sources pertinent to the Namoi catchment (Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2007; CEWO 2012; New South Wales Government: Office of Water 2011). Environmental and ecological data were used to derive the values of environmental water (Figure 2) based on available willingness-to-pay estimates for improved environmental conditions of rivers and wetlands in an Australian context. The values were derived by approximate matching of expected environmental conditions under alternative environmental water availability scenarios with willingness-to-pay estimates reported in a meta-analysis study by Brouwer (2009), which is based on eleven other Australian studies. While it cannot be claimed here that the derived values for environmental water are precise in any absolute sense, they adequately serve the purpose of the present study in terms of highlighting the differential benefits of environmental water across a range of hydro-climatic conditions.

The five types of benefit functions corresponded to the five possible states that a catchment can be in a given period/year: moderate conditions (Year Type 1), dry conditions (Year Type 2), very dry conditions (Year Type 3), wet conditions (Year Type 4) and very wet conditions (Year Type 5). The benefit functions for the five types of years are graphically presented in Figure 2.

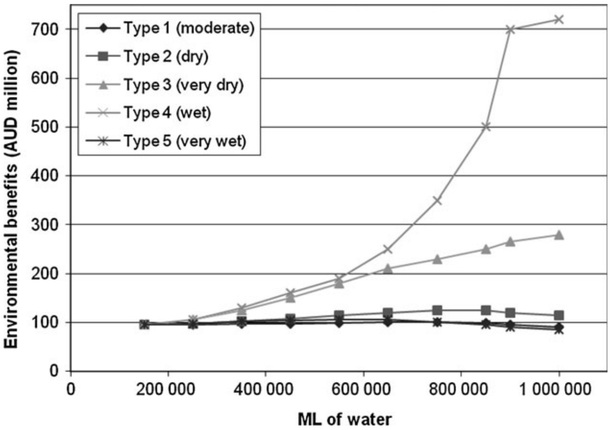

Figure 2 Benefit functions from environmental water flow across five types of annual hydro-climatic conditions.

Criteria (3) and (4) were designed to explore the possible effects of climate change, under expectations that mean water availability is likely to decline, and temporal variability of allocations is likely to increase. Criterion (5) was designed to test whether there are differences in benefits from water trade in periods of extended drought (eg. when wet periods are clustered together) compared to periods of shorter-term droughts (eg. when wet periods are spread out within a 10-year simulation).

Using the benefit functions for extractive and environmental water uses, simulations based on criteria (1)–(5) were conducted in a standard mathematical programming setup. This involved specifying the objective function and the relevant constraints and using a computer solver to allocate water to activities (using, buying or selling water) in an optimal way. For each simulation, the objective function that corresponded to the expression in Equation (1) was maximised subject to the stated constraints. Additional constraints could be specified in the mathematical program to reflect particular conditions that may be of interest. For instance, in some catchments, limitations on physical infrastructure may prevent beneficial water trade due to limited capacity to hold water for the environment within the system. The mathematical program was run for each of the five criteria for simulations stipulated above.

Particular hydro-climatic conditions were incorporated in the simulations through varying the level of water allocation to general security entitlements. The allocations were inversely related to the dryness of the conditions, that is, the dryer the conditions, the lower the allocations. This meant that the allocations were the lowest for year of Type 3 (very dry), followed by year of Type 2 (dry). Year of Type 1 (moderate) had average allocations, while year Type 4 (wet) had high allocations, with year Type 5 (very wet) having the highest allocations. The expected allocation and variance of allocations were varied between simulation scenarios as presented in Appendix tables.

5. Findings

A full set of results for alternative scenarios are provided in Table 1 and in appendix Tables A1–A12. The results show that when the environmental benefits are kept fixed across all years within a simulation, and across all hydro-climatic conditions (Type 1 year assumed throughout), overall benefits are slightly greater when CEWH actively participates in annual allocation market, compared to when it does not (Table 1). Overall benefits with CEWH trading are between 3.3 per cent and 5.5 per cent greater than benefits obtainable when CEWH does not trade. For the simulation that involves CEWH participating in annual water allocation trade, the predominant pattern of trade for the CEWH is net buying across individual years.

When the environmental benefits vary according to the hydro-climatic conditions, the overall benefits are between 5 per cent and 7.5 per cent greater when the CEWH participates in annual water allocation trade compared to when it does not. The greatest difference in benefits is recorded in relatively wetter decades, when 4 years out of 10 can be classified as ‘wet’ or ‘very wet’, with spread out wet years over the 10-year period (Tables A10–A12). This is closely followed by differences in benefits between CEWH participating or not in water trade in relatively drier decades when only 3 years out of 10 can be classified as ‘wet’ or ‘very wet’ (Tables A7–A9), with dispersed wet years across the 10-year period. Differences in benefits are somewhat lower when wet periods are clustered together – effectively simulating prolonged droughts – as presented in Tables A1–A6, but are still ranging between 5 and 5.5 per cent greater benefits when CEWH participates in water trade.

Simulations indicate that in many individual years it would be optimal for the CEWH to engage significantly in annual allocations trade. In some instances, all annual allocations held by the CEWH were sold, typically in moderate years following a wet period (year Type 1), and in others, annual

Table 1 Total benefits with and without Commonwealth Environmental Water Holder (CEWH) participating in trade, and CEWH’s predominant behaviour in the water market under constant hydro-climatic conditions (Year type 1 assumed throughout)

Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH behaviour in the market
10	381	402	Sells
20	434	455	Buys
30	481	507	Buys
40	522	550	Buys
50	556	586	Buys
60	584	614	Buys
70	605	634	Buys
80	619	645	Buys
90	627	649	Buys
100	629	650	No trade

allocations were bought by the CEWH, typically in wet years following a dry period (year Type 4).

Optimal trading behaviour of the CEWH is more reserved in moderate hydro-climatic conditions: some selling occurs in a second dry year in a sequence (year Type 2), and some buying occurs in the second wet year in a sequence (year Type 5). The CEWH is not very active in the annual water allocations market in the third dry year in a sequence (year Type 3).

In terms of actual quantity of water available for environmental purposes within a given year, the simulation results suggest that active participation of the CEWH in the annual allocation market is likely to secure greater quantity of water in those years when environmental water flows are needed the most. This is presented in Figures 3(a,b) showing that on average, participation of the CEWH in the annual allocation market increases the quantity of

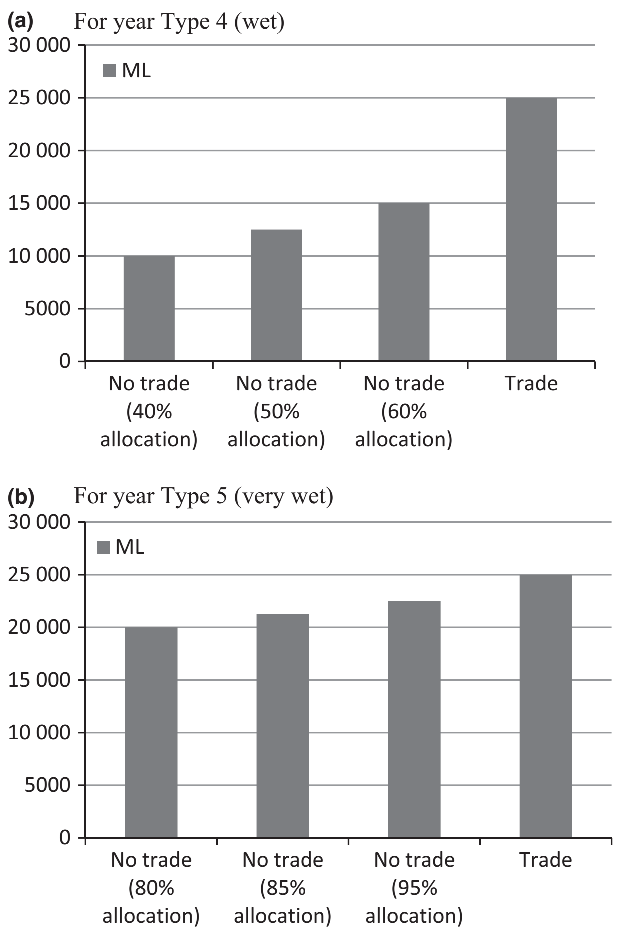

Figure 3 Available environmental water under alternative allocations, and participation of Commonwealth Environmental Water Holder (CEWH) in annual water allocations trade. (a) For year Type 4 (wet). (b) For year Type 5 (very wet).

environmental water by between 66 per cent and 150 per cent for a year of Type 4 (wet year after a dry period: wet hydro-climatic conditions) and by between 11 per cent and 25 per cent for year of Type 5 (second wet year in a sequence: very wet hydro-climatic conditions) in comparison with a situation when the CEWH does not trade. This indicates that active participation of the CEWH in annual water allocation market is more likely to ensure that adequate quantities of water are available for environmental purposes in periods when the marginal environmental contribution of additional water acquired through the water market is the greatest. The additional environmental water purchased in the allocation market in periods when river flows are already high can be used to instigate flood events that have significant ecological benefits.

Findings from the simulations further indicate that the pattern of optimal trading behaviour for the CEWH is robust to changes in the size of expected annual allocations and to their variability. The same optimal pattern of trade was observed across the scenarios encompassing high expected annual allocation and low variability of allocations, low expected allocations and high variability, and high expected allocations and high variability (Appendix tables).

When it comes to optimal trading behaviour of the CEWH with respect to scenarios where the wet or very wet years (Type 4 and Type 5) were clustered together or spread out, the findings suggest that trading was more beneficial in those decades that were characterised with spread out wet periods – total benefits with CEWH trading were on average 7 per cent greater compared to CEWH not trading – in relation to those decades that were characterised with clustered wet periods – total benefits with CEWH trading were on average 5.4 per cent greater compared to CEWH not trading. This indicates that trading in environmental water is likely to be relatively more beneficial in decades within which droughts are relatively short (last for a year or two) as compared to decades within which droughts are prolonged (can last for up to 4 years) (Tables A1–A3 vs A7–A9).

6. Implications and conclusions

Key implications from the findings of this study are that more active participation of the CEWH in the annual water allocation market is beneficial from society's perspective. An active role in this market allows the CEWH to buy water when it is needed the most for the environment and to sell water when the benefits to other water users are greater. This ensures that overall benefits to all water users and to society are maximised.

In particular, active trading in annual water allocations does not in any way compromise the dominant mission of the CEWH, which is to secure environmental and ecological well-being of the river systems. Given the evidence of varying benefits from environmental water flows across a range of hydro-climatic conditions, participation of the CEWH in the annual allocation market ensures that additional water can be purchased for environmental purposes at times when it is most opportune to supplement already high river flows, thereby causing flooding and flushing of the river system, which are necessary for periodic rejuvenation of the water-dependent ecosystems in and around Australian rivers. This means that it is better to buy some more water for environmental purposes in times when this is most beneficial and sell some environmental water to other users in times when the benefits from environmental water are relatively small, rather than to keep/carryover water for environmental purposes and abstain from trade.

Even when hydro-climatic conditions are treated as being constant across time, the findings of this study show that it is still more beneficial for the CEWH to trade in annual water allocations than not to. Consequently, it can be concluded that it is beneficial, economically sound and environmentally prudent to allow and to encourage the CEWH to actively participate in the annual water allocation market, certainly to an extent that is significantly greater than that proposed in the recent discussion paper prepared by the CEWH (2011).

The question remains as to what the rules should be that govern the trading behaviour of the CEWH in this market. While this study does not purport to answer that question explicitly, it does offer some insights about possible optimal trading patterns. These insights suggest that the CEWH should be selling annual allocations early in the drought period, that is, immediately after prolonged wet periods. Putting it in the perspective of the hydro-climatic situation in Eastern Australia of recent times, it is probably a reasonable strategy for the CEWH to be on the selling side of the annual allocations market in 2012–2013. Rivers and lakes have been full for some time; the alluvial plains have been recently flooded, and there is not a big benefit of sitting on the allocations to entitlements held on behalf of the environment. They would be much more beneficially used by irrigators or industry in these circumstances.

On the other hand, the CEWH should buy annual water allocations, and buy big, as the drought breaks. This will ensure that already high river flows are sustained and that limited flooding occurs to reinvigorate water-dependent ecosystems. This is critical for the purpose of building up the resilience of these ecosystems that will enable them to sustain dry periods in the future. In addition, water is much less needed for irrigation at these times, and annual allocations can be bought from irrigators at reasonable prices.

Overall, this study finds that there are significant benefits of the CEWH assuming a more active role in annual water allocation market. Political frictions may alter CEWH's willingness or ability to trade in allocations – such frictions are particularly pertinent to the Australian water markets because of a long history of political and commercial interests – and therefore comprise the attainment of benefits from trade in practice. Nevertheless, the findings from this study point to the desirability of CEWH participating actively in water markets.

Commonwealth Environmental Water Holder's water entitlements are already substantial, and are set to grow further. Actively managing these water entitlements, according to the prevailing current and preceding hydro-climatic conditions, by trading in annual water allocations is going to improve the environmental outcomes at times when they are most valuable and also provide a possibility for irrigators to buy extra water when it is not needed for the environment. Provided that all due diligence is undertaken within the mechanism for water trading, with the pre-eminent aim of the CEWH being to look after environmental needs in the MDB kept in the back of the mind, trading in annual water allocations can be a win-win outcome for the environment and for the people of the MDB.

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Appendix

Table A1 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 3 years out of 10 being wet or very wet and clustered together, and high expected annual allocation with low variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	40	526	555	−11,250
2	2	20	444	456	−5000
3	3	15	426	426	280
4	3	15	426	426	280
5	4	45	518	633	15,000
6	5	80	694	734	5000
7	5	80	694	734	5000
8	1	40	526	555	−11,250
9	2	20	444	456	−5000
10	3	15	426	426	280
Mean		37.5	512.4	540.1	−665.9
SD		25.5	104.4	123.6	7985.6

*The negative sign stands for the CEWH selling allocations.

Table A2 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 3 years out of 10 being wet or very wet and clustered together, and low expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	25	454	482	−6250
2	2	10	394	403	−2500
3	3	0	338	338	0
4	3	0	338	338	0
5	4	50	557	668	12,500
6	5	85	702	737	3750
7	5	85	702	737	3750
8	1	25	454	482	−6250
9	2	10	394	403	−2500
10	3	0	338	338	0
Mean		29	467.1	492.6	250
SD		33.3	141.2	162.7	5521.4

*The negative sign stands for the CEWH selling allocations.

Table A3 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 3 years out of 10 being wet or very wet and clustered together, and high expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	30	474	504	−7500
2	2	15	420	431	−3750
3	3	10	398	398	371
4	3	10	398	398	371
5	4	60	594	696	10,000
6	5	90	709	738	2500
7	5	90	709	738	2500
8	1	30	474	504	−7500
9	2	15	420	431	−3750
10	3	10	398	398	371
Mean		36	499.4	523.6	−638.628
SD		32.3	125.4	144.1	5264.7

*The negative sign stands for the CEWH selling allocations.

Table A4 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 4 years out of 10 being wet or very wet and clustered together, and high expected annual allocation with low variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	40	526	555	−11,250
2	2	20	444	456	−5000
3	4	45	518	633	15,000
4	5	80	694	734	5000
5	5	80	694	734	5000
6	5	80	694	734	5000
7	1	40	526	555	−11,250
8	2	20	444	456	−5000
9	3	15	426	426	280
10	3	15	426	426	280
Mean		44.0	539.2	570.9	−193.9
SD		27.4	113.7	130.2	8184.7

*The negative sign stands for the CEWH selling allocations.

Table A5 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 4 years out of 10 being wet or very wet and clustered together, and low expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	25	454	482	−6250
2	2	10	394	403	−2500
3	4	50	557	668	12,500
4	5	85	702	737	3750
5	5	85	702	737	3750
6	5	85	702	737	3750
7	1	25	454	482	−6250
8	2	10	394	403	−2500
9	3	0	338	338	0
10	3	0	338	338	0
Mean		37.5	503.5	532.5	625.0
SD		35.8	150.8	169.4	5628.9

*The negative sign stands for the CEWH selling allocations.

Table A6 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 4 years out of 10 being wet or very wet and clustered together, and high expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	30	474	504	−7500
2	2	15	420	431	−3750
3	4	60	594	696	10,000
4	5	90	709	738	2500
5	5	90	709	738	2500
6	5	90	709	738	2500
7	1	30	474	504	−7500
8	2	15	420	431	−3750
9	3	10	398	398	371
10	3	10	398	398	371
Mean		44.0	530.5	557.6	−425.8
SD		34.9	135.6	151.1	5352.4

*The negative sign stands for the CEWH selling allocations.

Table A7 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 3 years out of 10 being wet or very wet and spread over, and high expected annual allocation with low variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does t rade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	40	526	555	−11,250
2	2	20	444	456	−5000
3	3	15	426	426	280.327
4	4	45	518	633	15,000
5	5	80	694	734	5000
6	1	45	526	555	−11,250
7	2	20	444	456	−5000
8	3	15	426	426	280.327
9	3	15	426	426	280.327
10	4	45	518	633	15,000
Mean		33.5	494.8	530.0	334.1
SD		20.8	83.0	109.3	9293.0

*The negative sign stands for the CEWH selling allocations.

Table A8 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 3 years out of 10 being wet or very wet and spread over, and low expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: EWH does not trade in allocations ($ million)	Total benefits: EWH does trade in allocations ($ million)	EWH total trade activity (ML)*
1	1	25	454	482	−6250
2	2	10	394	403	−2500
3	3	0	338	338	0
4	4	50	557	668	12,500
5	5	85	702	736	3750
6	1	25	454	482	−6250
7	2	10	394	403	−2500
8	3	0	338	338	0
9	3	0	338	338	0
10	4	50	557	668	12,500
Mean		25.5	452.6	485.6	1125.0
SD		28.2	120.3	152.1	6704.3

*The negative sign stands for the CEWH selling allocations.

Table A9 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 3 years out of 10 being wet or very wet and spread over, and high expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	1	30	474	504	−7500
2	2	15	420	431	−3750
3	3	10	398	398	371.24
4	4	60	594	696	10,000
5	5	90	709	738	2500
6	1	30	474	504	−7500
7	2	15	420	431	−3750
8	3	10	398	398	371.24
9	3	10	398	398	371.24
10	4	60	594	696	10,000
Mean		33.0	487.9	519.4	111.4
SD		27.8	108.1	137.6	6210.8

*The negative sign stands for the CEWH selling allocations.

Table A10 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 4 years out of 10 being wet or very wet and spread over, and high expected annual allocation with low variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	4	45	518	633	15,000
2	5	80	694	734	5000
3	1	40	526	555	−11,250
4	2	20	444	456	−5000
5	3	15	426	426	280
6	3	15	426	426	280
7	4	45	518	633	15,000
8	5	80	694	734	5000
9	1	40	526	555	−11,250
10	2	20	444	456	−5000
Mean		40.0	521.6	560.8	806.1
SD		24.3	99.9	119.6	9409.1

*The negative sign stands for the CEWH selling allocations.

Table A11 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 4 years out of 10 being wet or very wet and spread over, and low expected annual allocation with high variance

Year	Type of year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	4	50	557	668	12,500
2	5	85	702	737	3750
3	1	25	454	482	−6250
4	2	10	394	403	−2500
5	3	0	338	338	0
6	3	0	338	338	0
7	4	50	557	668	12,500
8	5	85	702	737	3750
9	1	25	454	482	−6250
10	2	10	394	403	−2500
Mean		34.0	489.0	525.6	1500.0
SD		32.2	135.8	161.3	6739.2

*The negative sign stands for the CEWH selling allocations.

Table A12 Total benefits with and without CEWH participating in trade, and CEWH's total water trade activity under a scenario of 4 years out of 10 being wet or very wet and spread over, and high expected annual allocation with high variance

Year	Type of Year	Announced allocation to general security entitlements (per cent)	Total benefits: CEWH does not trade in allocations ($ million)	Total benefits: CEWH does trade in allocations ($ million)	CEWH total trade activity (ML)*
1	4	60	594	696	10,000
2	5	90	709	738	2500
3	1	30	474	504	−7500
4	2	15	420	431	−3750
5	3	10	398	398	371
6	3	10	398	398	371
7	4	60	594	696	10,000
8	5	90	709	738	2500
9	1	30	474	504	−7500
10	2	15	420	431	−3750
Mean		41.0	519.0	553.4	324.2
SD		31.7	123.1	146.0	6257.0

*The negative sign stands for the CEWH selling allocations.