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Buying Paper and Giving Gold: The Murray Darling Basin Plan

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Buying Paper and Giving Gold: The Murray-Darling Basin Plan

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Abstract

Two types of water property rights exist in the Murray Darling Basin: ground water and surface water. The latter has three distinct forms, high security, general security and supplementary. Their value is dependent on location and ability to supply water under known climate signals. This article suggests an optimal mix of property rights to allow the Basin Plan to achieve its objectives in obtaining 3,200 gigalitres of surface water. However, the solution exposes the Basin Plan's hidden gift of gold to irrigators, an extra 929 gigalitres of ground water extractions. The value of this gift increases under a changing climate.

Key words: Buy-Back, Climate Change, Property Rights, State-Contingent Analysis, Water property rights.

JEL Classification: Q25, Q54,

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1. Introduction

The ongoing 100-year policy experiment (Cummins and Watson, 2012) in the Murray-Darling Basin (hereafter Basin) entered a new phase in November 2012 when the Basin Plan was passed into law. The Basin Plan proposes to 'restore the balance' in allocations by transferring up to 3,200 gigalitres (GL) of surface water to the environment (Murray-Darling Basin Authority, 2012). This transfer is designed to offset the negative externalities, including salinity and environmental loss, from the current over-allocation of water resources to irrigators. The Water Act legislates that the transfer cost to the new sustainable diversion limits (SDL) is borne by the public and compulsory acquisition of irrigators' entitlements is illegal (Commonwealth of Australia, 2008). Over $10 billion has been allocated to facilitate the transfer of water from irrigators to the environment. This poses complex policy questions to determine if these transfers deliver net social benefits. Of the two strategies to obtain water, the 'Sustainable Rural Water Use and Infrastructure Program' (SRWUI) or capital works and measures has the largest budget. Initially the SRWUI was allocated $5.8 billion but the legislated Basin Plan provided an additional $1.77 billion to return an additional 450 GL of water to the environment (Murray-Darling Basin Authority, 2012). The Productivity Commission (2010) argued that the SRWUI is an inefficient and costly mechanism to return environmental flows when compared to purchasing water from the market, or when compared to the second strategy for returning flows called 'Restoring the Balance in the Murray-Darling Basin' (RtB). The RtB has a budget of $3.1 billion and is a tendering system designed to purchase water entitlements (that is, Buy-Back) from irrigators. That report argued that funds should be transferred to the RtB to improve the cost-effectiveness of the Basin Plan.

The RtB has also been widely supported by irrigators. As Cheesman and Wheeler (2012) found, 80% of irrigators believed the decision to sell water to the RtB was positive decision for their farming activities and at least 50% (exclusive of farmers without additional assets to sell) would consider participating in the program in the future. The willingness to participate was to take advantage of the higher prices offered by the RtB than on the open market. Crase and Gawne (2011) define four key requirements to optimise the RtB process: clear environmental goals; understanding the transmission losses between the point of purchase and environmental targets; the ability of alternative property rights to deliver water under existing and future climatic variability; and the timing schedule of rights. It is these key requirements that help explain the benefit of the Basin Plan increasing ground water extractions by 929 GL. In this article, ground water will be viewed as a constant supply, when compared to surface entitlements.

Dixon *et al.* (2011) used TERM-H_2O a computerised general equilibrium model to examine the buyback of 1,500 GL of water in the southern Basin. Dixon *et al*. (2011) illustrated that the process would have no detectable effect on the macroeconomic process. However, the nature of the TERM-H_2O prevents examining the key requirements to optimising the RtB process as described above.

This article illustrates how the RtB could be designed to achieve the Basin Plan's goals under a changing climate to maximise net social benefits. Social benefits are described as maximising economic rents from irrigation, subject to achieving the Basin Plans' targets on salinity and environmental flows under increasing climatic variability. This goal is achieved by adapting the state-contingent model of the Basin described in Adamson *et al.* (2009) to deal with four interconnected issues. First, illustrate irrigators' willingness to be involved in the RtB by modelling the economic incentives to sell alternative water entitlements under RtB budgetary constraints. Second, optimise the procurement solution to purchase an optimal bundle of entitlements to achieve the Basin Plans' targets on salinity and environmental goals. Third, examine changes to irrigated activity from the SDLs on surface and ground water. Fourth, explore the outcomes climate change could have on the three prior points.

The article is divided into five sections. The second section examines the objectives of the Basin Plan and provides a discussion on the RtB and water entitlements within the Basin. The third section outlines the modelling approach and describes in detail how the model described in Adamson *et al.* (2009) was adapted[2]. The results and discussion on purchasing an optimal portfolio of water entitlements in light of a changing climate are presented in section four. Section five provides the final comments concerning the Basin Plan.

2. The Basin Plan, Its Water Resources And Its Use.

Pannell (2009) articulates that for maximum economic benefits, policies designed to address natural resource externalities must have clear goals. When policy

[2] Case and Gawne's (2011) fourth requirement for optimal allocation, the inter-seasonal timing of water rights use cannot be examined due to the annual nature of the model used.

objectives understand that the law of diminishing marginal returns applies equally to natural resources, demand elasticities and production function discontinuities, economic growth is enhanced (Rostow, 1959). This understanding then helps estimate the trade-offs associated between the consumptive and non-consumptive uses of water thus highlighting “potential synergies and opportunities to maximise social returns from the government investment” (Mallawaarachchi *et al.*, 2010).

The Basin Plan has two primary objectives for non-consumptive water flow. One is to ensure that a minimum flow of 650 GL arrives at the Coorong every year; the other, to ensure that the dissolved salts in water diverted to the City of Adelaide do not exceed a threshold of 800 EC. To achieve these objectives the Basin Plan has stipulated a reduction water use from the Current Diversion Limits (CDL) to a Sustainable Diversion Limit (SDL). The trade-off questions are as follows: Does society benefit by purchasing water for the environment? What is the least cost bundle of entitlements required to achieve social objectives under existing and future climate scenarios? Is the compensation offered by the RtB and changes to ground water extraction, sufficient to achieve the Basin objectives? To examine these trade-offs, information about the Basin’s water resources, the value of entitlements, the proposed volumetric targets and future shocks to the resource base need to be discussed.

2.1 Current Water Use & Entitlement Structures

Current Diversion Limits (CDL) exceed 15,500 GL (Murray-Darling Basin Authority, 2012) or 59% of the Basin’s total average conjunctive water resources. However, irrigators own water entitlements rights of over 19,470 GL in four alternative entitlements classifications (Bureau of Meteorology, 2011), as shown in Table 1. This discrepancy is derived from spatial and temporal climatic variability and the over-allocation of rights degrading their real value creating ‘paper water’ (Cummins and Watson, 2012),

McMahon and Finlayson’s (1991) study of hydrological inflows into drainage basins determined that the Basin has the second most variable inflows in the world. This variability shaped the historical development of irrigation entitlements in each state and territory (MacDonald and Young, 2001). This article classifies these existing entitlements into four major groups, with decreasing levels of supply security: ground water, high security, general security and supplementary licences. Each catchment in the Basin has a bundle of entitlements representing the total volumetric allocations provided to irrigators on paper. The spatial reliability of these entitlements (see Table 2) has determined their market value for the RtB under known climatic signals (see Table 1). The data on reliability has been estimated in line with the CDL and the pricing data has been sourced from the RtB program.

2.2 The RtB Program

The RtB is a regional multistage tendering system featuring “budget-constrained, procurement-type [auctions]” (Schilizzi and Latacz-Lohmann, 2013). Irrigators know the total funds available to purchase water at a given location over a set time and they know the price of water in the temporary and permanent market. Irrigators who wish to participate submit non-binding expressions of interest stipulating the bundle of entitlements they are willing to sell for a given price (Hone *et al.*, 2010). This provides the government with complete temporal and spatial information to maximise environmental benefits (Latacz-Lohmann and Van der Hamsvoort, 1997). The tendering system has two additional features: successful tenderers can reject the offer; and the budget does not have to be exhausted.

Through time, price discovery will occur as the average price paid for successful bids is publically revealed. However, sellers logically knew that in order to obtain the assets the government would have to pay more than the market price (Cheesman and Wheeler, 2012). The data in Table 1 illustrates that as the reliability of the rights increase, their value increases. The annuity from selling water to the government is the annual return from investing any water sold at 7% (see Table 1). This value then helps determine the opportunity cost for irrigators from selling entailments or utilising assets within production systems. The option to sell water is modelled as a production system choice within the optimisation framework. Now that the price of assets is known, the proposed changes to water allocations need to be discussed

2.3 Proposed Changes to the CDL

The Basin Plan aims to achieve the surface SDL in two ways (see Table 3). First, a direct reduction in each catchment's SDL totalling 1,613 GL of water has been identified. Second, a further reduction from within five trading zones has been identified. It is expected that the water will be sourced from within these regions at least cost. Table 3 identifies the catchment by trading zone in the second column. The 'Southern All' trading zone requires an additional 450 GL to be returned from within all southern trading zones. The total volume of surface water to be derived from trading zones is 1,564 GL. This then equates to a total surface reduction of 3,194 (note the discrepancy in the 3,200 GL due to the Wimmera catchment not being modelled). While the increase in ground water extractions total some 929 GL providing a net reduction of 2,265 GL.

For simplicity, it has been assumed that all ground water is usable for irrigation. The cost of purchasing ground water in this article has been set to zero as it is assumed that this water is a by-product of the coal seam gas industry (Johnston and Ganjegunte, 2008).

2.4 Climate Variability, Climate Change & Water Use

Historically, two management approaches for dealing with water supply variability exist. First, a short run response of penalising environmental supply to maintain irrigator supplies are adopted, under the notion that in sequential time periods environmental flows are compensated. Second, announcements concerning the percentage of allocation to be delivered to irrigators, subject to the description of the entitlements risk, are made throughout the year requiring management solutions. The Basin Plan is designed to prevent the environment's share being used as an overdraft facility.

Irrigators adapt to the variable conjunctive supply of their water entitlement portfolios by altering both outputs (commodity produced) and input mix to maximise net returns through time. During the recent drought, dairy producers maximised their income by taking advantage of high prices on the temporary water market and used these funds to purchasing fodder (Ashton and Oliver, 2011). However, in times of extreme scarcity, where perceived known variances in water supply fail to hold (such as the severity and longevity of the recent drought), inflexible production systems (for example, perennial horticulture) fail to cope adequately in the short term and may result in net economic returns over the long run.

This is an issue for the RtB under a changing climate. If the optimal entitlements portfolio fails to consider adverse future changes to water supply, then the short run gains will fail in the long run. To examine this issue, the analysis compares two scenarios. First the RtB purchases all entitlements before the climate change event occurs (*ex-ante*) and the subsequent climate changes then impact on social and environmental objectives. The second has perfect insight of the climate change impacts (*ex-post*) and then purchases the optimal combination of entitlements.

Climate change in presented in two ways. First, a climate change scenario from the Garnaut Climate Change Review is used. Second, an examination of increasing drought frequency is examined. Australia's policy settings for climate change mitigation are derived from the Garnaut Climate Change Review. During that process, a number of alternative climate change scenarios were developed. The impact on water resources in the Murray Darling Basin are described in Quiggin *et al.* (2008). From that study, the best-case climate change scenario (450 Average) was chosen in to make this article comparable with other published material. This is described as the strong mitigation scenario, in which CO_2 equivalents are stabilised at 450 ppm by 2100. At this point mean global temperature is expected to increase by ~1.5°C. This scenario uses 50th percentile projections for rainfall, relative humidity and surface temperature across Australia. This study examines the impact on water resources in two time periods 2050 and 2100, which equates to approximately an average decline in water resources of 10% and 20% respectively.

The second approach of examining climate change is taken from Adamson *et al.* (2009). In that paper it was noted that the increasing frequency of drought state of nature forced greater adoption than a proportional reduction in average water resources. The examination of both approaches then illustrates the impacts of water variability and future water supply shocks to portfolio management.

By defining the location of the Basin's water entitlements, climate change, the cost to purchase entitlements, the Basin Plan's environmental and social targets we now need to determine the optimal combination of entitlements. To achieve this, the model must incorporate both the RtB budgetary constraints and the conveyance loss associated with transferring entitlements from one catchment to the next.

3. The Model & Assumptions

This article uses the state contingent approach to risk and uncertainty and adapts the model of the Basin described in Adamson *et al.* (2009). Arrow (1953) and Debreu (1959) provided the insight into the state-contingent process. They argued that that by describing all future outcomes with a complete set of states of nature uncertainty could then be treated as problems with complete certainty. By allowing irrigators to actively respond to the each state of nature by either: changing both the inputs they use (for example, water and labour); the product they produce (for example, whether to stop irrigation and produce a dryland crop); and the technology used to produce output, the approach then overcomes the limitations of a stochastic response to modelling uncertainty where the climatic signal and the management response cannot be separated (Quiggin and Chambers, 2000).

The following summarises the changes to model for this article. The complete data sets and results can be obtained from the corresponding author. For this article the model is solved from the national good perspective where a single individual can allocate all resources throughout the Basin to achieve the maximum possible return (Equation 1) subject to a set of constraints (Equations 5 to 10).

$$MaxE[Y] = \sum_{K} \sum_{s \in \Omega} \pi_s \left(R_{s,k} - C_{s,k} \right) \tag{1}$$

Where

Revenue: $$r_{s,k} = z_{s,k} p_{s,k} \tag{2}$$

Costs $$c_{s,k} = a_{s,k}{}' x_{s,k} \tag{3}$$

Output $$z_{s,k} = f(x_k) \tag{4}$$

Subject to

$$b_{s,k} x_{s,k} \leq B_{s,k} \tag{5}$$

$$x_s \geq 0 \tag{6}$$

$$w_{s,k} \leq wf_{s,k} \tag{7}$$

$$\sum W\pi_s \leq Cap \tag{8}$$

$$wf_{s,21} \geq 650\ GL \tag{9}$$

$$\sigma_{s,20}/0.64 \leq 800\ \mathrm{EC} \tag{10}$$

Symbol	Definition
$E[Y]$	Expected [Income]
K	Catchments in the Basin $(K = 1 \ldots 21)$
S	States of Nature $(S = 1..3)$
π	Probability of state occurrence
R	Revenue
C	Costs
Z	Output
P	Price per unit of output
x	Vector of activities
A	Vector of input prices (land, fixed costs, variable costs, water)
b	Vector of input requirements (land, fixed costs, variable costs, water)
B	Input constraints (land, water)
w	Volume of water used derived from $b_{s,k}x_{s,k}$
wf	Volume of water flowing in the catchment
Cap	The total constraint on the water use. Depending on run ether based on CDL or SDL data.
σ	Salinity level in EC units

3.1 Production Systems

To model both the change in ground water resources and the RtB program, the production systems have been altered as follows. The model has expanded the total number of production systems to 47 in each state of nature. This consists of 21 production systems produced only with ground water and the remainder allocate surface water. Surface water can be used by 21 production systems, or irrigators can sell three classifications of water entitlements (high security, general security and supplementary). By treating water sales as an annuity, they can be treated as production systems, creating a clear trade-off with other production options. The water sold by farmers is then entered directly into the flow equations below as additional conjunctive resource. Of the remaining two production systems, one is used to model Adelaide's water supply and the other provides a default dryland production system so that irrigation land can transition out.

All inputs for the productions systems were derived from regional enterprise budgets and other sources. For simplicity, it was assumed that all inputs, costs and the output of each commodity are identical regardless of the production system being produced by ground or surface water. Unlike the previous versions the constraints concerning operator labour have been relaxed on the assumption that labour would enter the market to take advantage of opportunities. The other rules concerning horticulture and total area dedicated to irrigation still apply but are not presented here.

3.2 Interaction between water & salinity

The Basin is modelled as a directed flow network across 21 catchments. Conjunctive exogenous water resources θ include surface flows, ground water extractions and net inter-basin transfers. The states of nature are defined by a proportional change to the normal state's θ, where the drought state is 0.6θ and the wet state is 1.2θ. The model assumes that the probability of a drought, normal and wet states is 0.2, 0.5, and 0.3 respectively. In this article, to model the difference between ground and surface water, ground water is modelled as a separate resource but return flows from ground water use does enter the model (see Equation 10).

The flow leaving each catchment $wf_{s,k}$ is obtained from Equation 10.

Here the flow is determined by the impact that conveyance losses wc have on water resources θ, minus water used w to irrigation less return flows wr from its use, plus the return flows from the ground water used $wrg_{s,k}$ and includes the volume of water purchased from the RtB program we. When this water reaches the next catchment it forms part of θ and conveyance losses are then applied. In this manner the trade-offs between the spatial acquisition of entitlements to environmental and social benefits can be determined:

$$wf_{k,s} = \left(\theta_{s,k} \cdot wc_{s,k}\right) - \left(w_{s,k} - wr_{s,k}\right) + wrg_{s,k} + we_{s,k} \tag{10}$$

For each production system $x_{s,k}$ a defined water use and reflow variable by technology option exists, providing the capacity to examine changes in capital investment in water saving technology. Water quality is simplified to reflect salinity σ as it is a binding policy constraint to ensure that the Basin Plan's requirement for the City of Adelaide's water quality is achieved (Equation 11). σ is a ratio of the salt load G and f where:

$$\sigma_{s,k} = G_{s,k}/wf_{s,k} \tag{11}$$

$G_{s,k}$ is a combination of the naturally mobilised exogenous tonnes of salt that enters with $\theta_{s,k}$ less the exogenous tonnes of salt removed via the salinity mitigation program, plus the endogenous salt transported with reflow determined by $\theta_{s,k}w_{s,k}$.

Without a detailed environmental plan in the Basin Plan, Equation 9 provides the only environmental target for this model. This ensures that 650 GL of water arrives to the Coorong in all states of nature.

3.3 The Bain Plan & Purchasing property rights

Water used for irrigation is constrained by $wf_{s,k}$ (Equation 7) and the Basin Plan's exogenous sustainable diversion limits (Equations 8). However to model the Basin Plan, Equation 8 has to be transformed into Equations 12 to19. As discussed the current plan stipulates both a reduction by k and a defined volume to be sourced from within interconnected or state based trading regions (Table 3).

Of the two,' termed' unconnected systems only the Lachlan (*k* = 9) is included within the model. Within the identified trading zones the model has assumed free trade to obtain water at least cost for the environment. The model considers all water diverted for irrigation is used on farm and does not track conveyance losses in built capital infrastructure. These equations allow irrigation water can to be carried over between states of nature by only requiring water on average to equal the specified SDL.

Equation 19 provides the RtB budgetary constraint for the model. This equation ensures that at least the requirements of the SDL are matched to the optimal bundle of entitlements subject to cost.

$$\sum w^k \ \pi_s \ \leq \sum SurfaceSDL^k \tag{12}$$

$$\sum w^k \ \pi_s \ = \sum GroundSDL^k \tag{13}$$

$$\sum w^{NTV} \pi_s \ \leq \ 143 \ GL \tag{14}$$

$$\sum w^{STV} \pi_s \ \leq \ 425.3 \ GL \tag{15}$$

$$\sum w^{STN} \pi_s \ \leq \ 462.9 \ GL \tag{16}$$

$$\sum w^{STS} \pi_s \ \leq \ 82.8 \ GL \tag{17}$$

$$\sum w^{STA} \pi_s \ \leq \ 450 \ GL \tag{18}$$

$$\sum_K (WE \cdot EP \ \cdot ER_S) \, \pi_S \ \geq \ (SurfaceCDL - SurfaceSDL)\pi_S \ \leq \$3.1 \ Billion \tag{19}$$

Symbol	**Definition**
$SurfaceSDL$	Total volume of surface water allowed for irrigation use
$GroundSDL$	Total volume of ground water allowed for irrigation use
NTS	Water trading zones in the northern catchments ($k \ = 1 \dots 8$)
STN	Water trading zones in the southern New South Wales catchments ($k \ = 10, 12, 14, 16, 18$)
STS	Water trading zones in the southern South Australian catchments ($k = 19$)
STV	Water trading zones in the southern Victorian catchments ($k = 11, 13, 15, 17$)
STA	Water trading zones in all southern catchments ($k = 10 \dots 19$)

WE	Water entitlements
EP	Water price is the cost to purchase entitlements (Table 1).
ER	Entitlement reliability is the volume of water available by *s* (Table 2).

4. Results & Discussion

4.1 Comparison of the SDL to CDL

The results from the analysis are provided in Table 4 to Table 10. Table 4 outlines the Basin Plan's change to the combination of total surface and ground water extractions are provided. Under the SDL scenario with the current climatic conditions, ground water use increases by 929 GL in all states of nature. While the net reduction in surface water use on average is 2,488 GL with a range of 1,634 GL less surface water used in the drought states of nature and 3,122 GL less used in ideal conditions. This data suggests that the environment is only likely to receive the Basin Plan's objectives of returning 3,200 GL of water when there is no scarcity. However, even in the drought state the SDL is expected to increase the flow to the Coorong by over 1,172 GL, an increase in over 629% compared to the CDL 186 GL, see Table 8.

This is achieved by obtaining 184,000 high security licences costing $386 million, 1,876,000 general security licences costing $1,931 million and 3,017,000 supplementary water entitlements costing $783 million, see Table 9. The expenditure by catchment is detailed in Table 10. The water assets are expected to return 2,641 GL on average to the Basin. The difference between water used and return flow to the Basin is due in part to selling water entitlements that are underutilised in the production systems. This finding is consistent with Cheesman and Wheeler (2012) finding where water sales would not impede irrigators activities.

Due to conveyance losses along the system, the 2,641 GL equates to only 562 GL on average arriving to the Coorong, Table 8. Overall, despite a reduction in total water use by 10% (Table 4) the economic return is expected to increase by $212 million on average, an increase of 7% (Table 5). Importantly, this increase in return is noticeable in the drought state of nature when the funds are needed most. This increase is driven primarily by the $293 million in annuity from water sales and an increase of $179 million from ground water usage. These two increases offset the $90 million in contraction due to reduced surface water entitlements. This confirms the findings of Dixon *et al.* (2011) where the price paid under the RtB for assets adequately compensates irrigators. However, the new SDL for both surface and ground water assets creates secondary impacts on net farm assets values as the policy creates discrepancies in the net return per megalitre (ML) (Table 6). The net return for ground water increases by $14 per ML while the net return from surface water reduces by $9.50 per ML compared to the CDL. This difference is due to the reliability of the assets and as illustrated under a changing climate this difference increases as surface water security reduces. This net change in asset description will create second round winners and losers. It is likely that the annuity value could be used to fund on-farm adaptation that would compensation the reduction in reliability of surface water entitlements dampening the divergence in returns.

The increased access to secure ground water (Table 3) then encourages the development of perennials in the northern Basin, Lachlan, Mallee and South

Australia. As previously discussed these perennials may reduce future flexibility if the description of unutilised resources by the Basin Plan is incorrect, exposing capital to climatic variability.

4.2 Impacts of a changing climate

If the RtB is optimised without considering the long-term impacts of a changing climate (*ex-ante*) then the SDL solution for the social and environmental benefits rapidly reverts into the CDL run (Table 8). By 2050, the 10% decline in water resources diminishes the SDL solution flowing to the Coorong by 1,141 GL on average with a range of 584 GL less in the drought state of nature and 1,598 GL in the wet states of nature. Although there is an improvement on the CDL solution in the drought, there is less water flowing to the Coorong in the normal and wet states. This effectively leads to a situation where water quality on average does not improve. By 2100, all environmental and social goals are lost. If we compare the *ex-ante* and *ex-post* solutions we can see that being aware of climate change provides better social and ecological outcomes. Although climate change does reduce the outcomes of the RtB, the solutions are generally better in terms of flow and water quality when compared to the *ex-ante* solutions.

Once the 450 climate change is revealed (*ex-post*), when compared to the SDL, we see that initially in 2050 that the surface reductions initially contract in the drought state of nature (i.e. 1,586 GL compared to 1,634 GL) and the environment receives a far greater share of its resources only in the wet. However, once the 2100 scenario occurs the 20% reduction in surface flows forces the optimal combination of entitlements to shift from supplementary entitlements to general security entitlements

(Table 9), causing an optimised RtB expenditure shift to focus towards both an increase in general security entitlements away from supplementary license to ensure water supply in the droughts. This then creates a new suggested budgetary expenditure targeting different catchments (Table 10). By targeting expenditure to specific catchments it directly tackles the trade-offs between transmission losses, reduced economic activity and RtB budgetary constraints. The social constraints for salinity targets and environmental flow are achieved (Table 5) at the cost of irrigators output (Table 8). Here as the available level of surface water decreases, the net water used contracts with by 2,218 GL in the drought states of nature (Table 4). Despite the climate change run the reducing total surface supply by 20%, the total average used by irrigators only contracts by 15% when compared to the CDL. However, the optimisation solution still provides an increase, on average, by 1%. This occurs as the environment shares in the contraction of resource availability under a changing climate.

4.3 The role of droughts

The Increasing frequency of drought states has a different impact to the climate change solutions. As Table 4 illustrates, the transition to optimal combination of resources suggests that despite this scenario using 2,688 GL of surface water on average less than the CDL it still uses, on average, 200 GL more than the SDL solution. This is achieved by significantly altering when the surface water is used in comparison to the SDL scenario. This illustrated in Table 7, in which the change in area is presented. Increasing droughts concentrate the expansion in area utilised by increased access to ground water resources and contracts the area irrigated by surface diversion in all states of nature when compared to the SDL. There is a net reduction in the area irrigated by 193,000 Ha when compared to the CDL solution. Despite this contraction in area, especially in the drought, the net return from the water utilised increases when compared to the SDL (Table 5). In this case, the solution chooses an alternative set of commodities to minimise net loss in the droughts. This solution is consistent with the findings in Adamson *et al.* (2009). In this case, despite a 12% reduction in water for irrigation, there is a 7% increase in economic return due primarily to the increasing value of ground water reserves (Table 6).

To achieve the environmental and social goals the optimal mix of water entitlements allocates a greater proposition of the budget to general security licences ($1,976 million) but buys less general security licenses than the SDL solution (Table 9). This occurs as the model purchases more expensive water in the North Central than in the Goulburn Broken catchment (Table 1). Here the model has traded off the conveyance losses in water flowing (Table 9) over a greater distance over price and economic return. By ensuring that water is available in the drought state of nature the social and environmental objectives in the drought state of nature exceed the benefits compared to the SDL solution (Table 8). On average, the SDL provides better outcomes for the social objectives of the Basin Plan.

Concluding comments

The analysis suggests that the $3.1billion RtB program could achieve the stated Basin Plan's objectives under a changing climate. Even with the limits of the model, a net wealth transfer to irrigators is evident. The wealth transfer could be justified from a social point of view as the Basin Plan is designed to reduce the dead weight social cost of externalities leading to net gains. However, the artificial constraints of predetermined SDL volumes to be returned by catchment and by trading zone will inflate the prices paid to obtain property rights. The correct optimisation question should have been: “what optimal bundle of entitlements could achieve the social objectives at least cost under increasing climatic uncertainty?”

By determining the trade-offs between consumptive and non-consumptive objectives optimal combination of entailments can be examined. However, until the complete set of environmental objectives is known, the way the Commonwealth Entitlement Water Holder manages their bundle of assets cannot be examined. This has two complications for the results. First, the optimal bundle of goods needs to be targeted to these goals increasing costs thus justifying the Productivity Commission’s (2010) recommendation to transfer more funds to the RtB program. Second, the timing of the environmental watering plans may be counter the irrigators’ needs preventing irrigator supplies piggybacking on environmental water. This issues as identified by Crase and Gawne (2011) can be dealt with within the current version of this model.

The article suggests that as climate continues to change, the future reliability of alternative surface water entitlements will be discounted further while the holders of the golden groundwater receive increasing asset values. This was a deliberate decision to illustrate the Basin Plan suggestion that ground water resources are underutilised. Under a changing climate, the recharge rates to ground water will reduce, leading to revised reliability rates in the long run, creating a call for further compensation. Until then a key adoption response for irrigators will be to take advantage of the ability to transfer surface entitlements in ground water assets as allowed by the Basin Plan. This could create an over-exploitation of resources (either by agriculture or mining) then the visible consequences of over-allocated surface water will be transferred to invisible ecological impacts below ground (MacDonald and Young, 2001).

To examine the above issue, the adoption of a stochastic description of the ability of water rights to deliver water under alternative states of nature is needed to expose the unreliability of rights under scarcity. The new solution would either be met with an increased purchase of rights or a relaxation of the social benefits, or both. Quite simply, no-one can have access to an asset if it is not there.

The assets sales to the RtB provide farmers with flexibility. It provides an additional source of income that they can either use to adapt (or pay down debt) or transfer out of farming. As Dixon *et al.* (2011) articulate the wealth transfer to irrigators negates any real losses in the second round. If anything the reduction in available surface water entitlements (in the Sothern Basin) in the short-run would increase farm equity. This equity then provides the impetus to invest in water saving technology creating further wealth. This is where the RtB and the SRWUI diverge. The RtB returns water through licences and the SRWRUI attempts to return through farm efficiency. In short the SRWRUI does not reduce the volume of water to irrigate with therefore there is no increased equity to offset the increased debt required to obtain the efficiency. Therefore the SRWRUI needs to be investigated to determine the following questions: who receives the estimated budget of $7.57 billion and is it purely a net wealth transfer? Does the SWRUI increase the reliability of water supply and what happens to the ability of water efficient industries to deal with climate change? What is the story of return flows from irrigation?

One possible solution is to revisit Davidson (1969) and reiterate his findings. Should the remaining funding be allocated as a wealth transfer to the irrigation industry or invested in research and development that may provide benefits across dryland and irrigated producers Australia-wide? Unfortunately an economic reply and a political reply exist. Thus, as we enter the next 100 years of this on-going experiment the countdown to the next wealth transfer has begun.

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Table 1: Entitlements by Catchment, Costs to Purchase, Annuity Value

Catchment	Entitlement Security (ML) †				Cost to Purchase ($/ML) ‡			Annuity from Water Sale ($/ML)		
	Ground	High	General	Supplementary	High	General	Supplementary	High	General	Supplementary
Condamine	132			1,398			$860			$81.14
Border Rivers QLD	24			587			$860			$81.14
Warrego Paroo	2			125	$0	$0	$161			$15.20
Namoi	224	5	286	255	$2,050	$1,593	$161	$193.51	$150.39	$15.20
Central West	99	18	632	143	$2,050	$1,268	$161	$193.51	$119.69	$15.20
Maranoa Balonne	88			932			$161			$15.20
Border Rivers Gwydir	108	16	773	375	$2,922	$860	$161	$275.80	$81.14	$15.20
Western	79			196			$161			$15.20
Lachlan	393	31	615	68	$2,050	$683	$161	$193.51	$64.47	$15.20
Murrumbidgee	355	377	1,888	697	$1,704	$914	$218	$160.85	$86.28	$20.58
North East	0	196	79	61	$1,933	$1,133	$193	$182.46	$106.95	$18.22
Murray 1	6	6	50	20	$1,967	$1,133	$193	$185.67	$106.95	$18.22
Goulburn Broken	486	1,221	706	139	$2,059	$1,122	$196	$194.33	$105.89	$18.46
Murray 2	96	96	834	334	$1,967	$1,133	$196	$185.67	$106.95	$18.46
North Central	0	913	432	161	$2,065	$1,133	$199	$194.93	$106.95	$18.80
Murray 3	87	86	750	301	$1,967	$1,122	$199	$185.67	$105.89	$18.80
Mallee	70	156	73	12	$2,066	$1,133	$199	$195.02	$106.95	$18.78
Lower Murray Darling	4	11	111	275	$1,967	$1,107	$161	$185.67	$104.49	$15.20
SA MDB	120	449	0	0	$2,099			$198.13		
TOTAL	**2,373**	**3,582**	**7,230**	**6,081**						

† Bureau of Meteorology (2011)
‡ SEWPaC (2013)

Table 2: Estimated Reliability of Entitlements by Climate State (%)

Catchment	Normal			Drought			Wet		
	High	General	Supplementary	High	General	Supplementary	High	General	Supplementary
Condamine			0.20			0.15			0.60
Border Rivers QLD			0.40			0.30			0.60
Warrego Paroo			0.30			0.20			0.60
Namoi	1.00	1.00	0.40	0.75	0.40	0.20	1.00	0.90	0.60
Central West	1.00	0.60	0.25	0.75	0.25	0.15	1.00	0.75	0.60
Maranoa Balonne			0.20	0.75	0.20	0.15	1.00	0.80	0.60
Border Rivers Gwydir	1.00	0.55	0.20	0.75	0.15	0.10	1.00	0.80	0.55
Western			0.50			0.20			0.60
Lachlan	1.00	0.40	0.30	0.75	0.15	0.10	1.00	0.75	0.60
Murrumbidgee	1.00	0.80	0.35	0.75	0.40	0.20	1.00	0.90	0.80
North East	1.00	0.85	0.15	0.75	0.50	0.05	1.00	0.95	0.75
Murray 1	1.00	0.85	0.15	0.75	0.50	0.05	1.00	0.95	0.75
Goulburn Broken	1.00	0.85	0.15	0.75	0.50	0.05	1.00	0.95	0.75
Murray 2	1.00	0.85	0.15	0.75	0.50	0.05	1.00	0.95	0.75
North Central	1.00	0.85	0.15	0.75	0.50	0.05	1.00	0.95	0.75
Murray 3	1.00	0.85	0.15	0.75	0.50	0.05	1.00	0.95	0.75
Mallee	1.00	0.70	0.15	0.75	0.40	0.05	1.00	0.80	0.75
Lower Murray Darling	1.00	0.50	0.10	0.75	0.20	0.05	1.00	0.80	0.60
SA MDB	1.00			0.80			1.00		

Data matched to existing CDL

Table 3: The Net Change in Extractions by Catchment & Region

Catchment	Trading Zone	Net Change in Volume (GL)	
		Ground Water	Surface Water
Condamine	Northern	62.8	-60.0
Border Rivers QLD	Northern	47.8	-8.0
Warrego Paroo	Northern	132.0	-9.0
Namoi	Northern	0.0	-10.0
Central West	Northern	8.6	-65.0
Maranoa Balonne	Northern	41.9	-40.0
Border Rivers Gwydir	Northern	128.7	-49.0
Western	Northern	95.5	-6.0
Lachlan	Unconnected	123.3	-48.0
Murrumbidgee	Southern NSW	0.0	-320.0
North East	Southern VIC	0.0	-32.9
Murray 1	Southern NSW	0.1	-7.9
Goulburn Broken	Southern VIC	32.3	-369.3
Murray 2	Southern NSW	1.3	-131.0
North Central	Southern VIC	0.0	-194.5
Murray 3	Southern NSW	1.1	-117.9
Mallee	Southern VIC	142.7	-30.4
Lower Murray Darling	Southern NSW	0.1	-13.2
SA MDB	Southern SA	111.3	-101.0
	TOTAL	**929.2**	**-1,613.0**
Further Reduction Trading Zones		Northern	-143.0
		Southern NSW	-425.3
		Southern VIC	-462.9
		Southern SA	-82.8
		Southern All	-450.0
	Reduction in the Trading Zones		**-1,564.0**
	TOTAL Surface Reductions		**-3,194.0**
TOTAL Net Change (Ground + Surface)			**-2,265.0**

Data From (Murray-Darling Basin Authority, 2012)

Table 4: Results, Total Water Used by Scenario, from Ground Water Extractions and Surface Water Diversions

Scenario	Ground Water All states (GL)	Surface Water (GL) Normal	Drought	Wet	Average	TOTAL Diversions (GL) Normal	Drought	Wet	Average	% Change (Average)
CDL	2,373	12,013	6,899	17,632	12,676	14,386	9,272	20,004	15,049	
SDL	929	-2,449	-1,634	-3,122	-2,488	-1,520	-704	-2,193	-1,559	-10%
450, 2050, *ex-post*	929	-2,664	-1,586	-3,809	-2,792	-1,735	-657	-2,880	-1,863	-12%
450, 2100, *ex-post*	929	-2,768	-2,218	-4,411	-3,151	-1,839	-1,289	-3,481	-2,222	-15%
Drought States, *ex-post*	929	-1,375	-1,838	-1,878	-2,688	-446	-909	-949	-1,759	-12%

Table 5: Economic Return by Scenario, from Ground Water, from Surface Diversions and from Asset Sales.($'m)

Scenario	Ground Water Normal	Drought	Wet	Average	Surface Water Normal	Drought	Wet	Average	RtB All	TOTAL Economic Return Normal	Drought	Wet	Average	% Change (Average)
CDL	$591	$358	$917	$642	$2,397	$848	$3,570	$2,439		$2,989	$1,206	$4,487	$3,082	
SDL	$274	$179	$423	$300	-$349	-$90	-$626	-$380	$293	$218	$382	$90	$212	7%
450, 2050, *ex-post*	$280	$168	$440	$305	-$443	-$117	-$708	-$457	$293	$129	$343	$25	$141	5%
450, 2100, *ex-post*	$344	$183	$593	$387	-$547	-$184	-$1,085	-$636	$293	$89	$291	-$199	$43	1%
Drought States, *ex-post*	$362	$223	$619	$411	-$305	$31	-$1,112	-$480	$293	$350	$547	-$201	$224	7%

Table 6: Value of Alternative Water Resources for Irrigators ($/ML)

	Ground Water	Surface Water
CDL	$270.77	$162.10
SDL	$14.64	-$9.45
450, 2050, *ex-post*	$16.31	-$11.78
450, 2100, *ex-post*	$40.86	-$21.49
Drought States, *ex-post*	$48.34	-$14.65

Table 7: Land Allocated to Irrigation from Ground Water, Surface Water by Scenario

	Area Produced ('000 Ha) by									% Area Change (Average)	
	Ground Water	**Surface Water**				**TOTAL**				**Ground**	**Surface**
Scenario	**All states**	**Normal**	**Drought**	**Wet**	**Average**	**Normal**	**Drought**	**Wet**	**Average**	**Water**	**Water**
CDL	474	1,744	1,261	2,231	1,794	2,218	1,735	2,705	2,268		
SDL	200	-308	-291	-334	-312	-108	-91	-134	-112	42%	-17%
450, 2050, *ex-post*	241	-314	-258	-399	-328	-73	-17	-158	-87	51%	-18%
450, 2100, *ex-post*	258	-507	-460	-649	-540	-249	-202	-391	-282	54%	-30%
Drought States, *ex-post*	149	-315	-410	-308	-342	-166	-261	-159	-193	31%	-19%

Table 8: Results for the Social Objectives, Flow to Coorong (GL) and Adelaide's Water Quality (EC), With and Without Accounting for Climate Change in the RtB Strategy, Results Compared to CDL and SDL

Scenario	**Flow to Coorong (GL)**				**Adelaide Salinity (EC)**				**% Change (Drought)**	
	Normal	**Drought**	**Wet**	**Average**	**Normal**	**Drought**	**Wet**	**Average**	**Coorong**	**Salinity**
CDL	3,739	186	9,046	4,621	423	687	328	448		
Compared to CDL										
SDL	631	1,172	39	562	-49	-361	2	-96	629%	-53%
450, 2050, *ex-post*	-310	550	-1,366	-455	22	-229	48	-21	295%	-33%
450, 2100, *ex-post*	-1,461	464	-2,913	-1,512	183	-252	122	78	249%	-37%
Drought States, *ex-post*	-122	1,333	349	-477	36	-393	-18	-68	715%	-57%
450, 2050, *ex-ante*	-459	589	-1,559	-579	54	-234	68	0	316%	-34%
450, 2100, *ex-ante*	-1,680	-65	-3,349	-1,857	266	114	180	210	-35%	17%
Compared to the SDL										
450, 2050, *ex-ante*	-1,090	-584	-1,598	-1,141	103	127	65	96	-50%	-35%
450, 2100, *ex-ante*	-2,311	-1,237	-3,388	-2,419	315	476	178	306	-106%	-132%

Table 9:Optimal Combination of Entitlements, Their cost by Scenario and the Water returned to the Environment

Scenario	**Water Rights Bought by Security ('000)**			**Program Cost ($'m)**				**Volume Returned (GL)**			
	High	**General**	**Supplementary**	**High**	**General**	**Supplementary**	**TOTAL**	**Normal**	**Drought**	**Wet**	**Average**
SDL	184	1,876	3,017	$386	$1,931	$783	$3,100	2,352	1,324	4,002	2,641
450, 2050, *ex-post*	184	1,942	2,940	$386	$2,022	$693	$3,100	2,356	1,319	3,998	2,641
450, 2100, *ex-post*	184	1,970	2,895	$386	$2,055	$659	$3,100	2,362	1,319	3,992	2,642
Drought States, *ex-post*	184	1,859	3,017	$386	$1,976	$738	$3,100	2,356	1,349	3,998	2,382

Table 10: Expenditure on Entitlements by Catchment ($'m)

Scenario	**SDL**	**450, *ex-post* 2050**	**450, *ex-post* 2100**	**Increasing Droughts**
Condamine	$258	$162	$129	$202
Border Rivers QLD	$14	$14	$14	$14
Warrego Paroo	$3	$3	$3	$3
Namoi	$3	$3	$3	$3
Central West	$31	$80	$107	$31
Maranoa Balonne	$50	$68	$74	$60
Border Rivers Gwydir	$21	$21	$22	$21
Western	$2	$2	$2	$2
Lachlan	$32	$32	$32	$32
Murrumbidgee	$872	$839	$839	$604
North East	$19	$19	$19	$102
Murray 1	$4	$4	$4	$4
Goulburn Broken	$819	$569	$688	$819
Murray 2	$65	$65	$65	$65
North Central	$307	$522	$402	$522
Murray 3	$60	$60	$60	$60
Mallee	$40	$86	$86	$86
Lower Murray Darling	$116	$168	$168	$85
SA MDB	$386	$386	$386	$386
TOTAL	**$3,100**	**$3,100**	**$3,100**	**$3,100**

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