Basin Plan CGE Modelling using TERM-H2O

Report prepared by

Glyn Wittwer

Centre of Policy Studies, Monash University

for the

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Executive Summary

The main scenario: an SDL target of 2800 GL

This study differs from a previous study using TERM-H2O commissioned by the MDBA (Wittwer 2010):

- The SDL target entails purchases of 2800 GL of water from farmers by 2019. In Wittwer (2010), SDL targets modelled were 3500 GL, 3000 GL and 4000 GL.
- The theory of TERM-H2O has been modified to reflect more closely observed changes in dairy cattle production, in particular, in response to changes in water availability. The main impact of this change is that more of the adjustment to lower water availability occurs through a movement of dairy cattle from irrigated to dry-land production technologies.

The headline basin-wide impact of fully implemented SDLs is that there is little change in overall economic activity. The most notable impact is a movement of farm activity from irrigation to dry-land technologies, with a substantial contribution from the dairy sector. Given that the process of environmental water purchases involves willing sellers who are paid a market price, this result is not surprising. Farmers who are fully compensated will be no worse off from water sales, and indeed would not be motivated to sell if this were the case.

TERM-H2O is a dynamic CGE (computable general equilibrium) model. In the main scenario and its variants, it is run from 2008 to 2029. The final year is a full decade after the SDL target has been attained. Basin-wide real GDP falls by 0.29 percent relative to the baseline by 2029.[1] Employment in the basin falls by 0.1 percent, or around 600 jobs. An initial surprise is that real household consumption in the basin rises by 0.14 percent relative to the baseline in 2029. This gain has two main sources: first, we treat buyback proceeds as an annuity, which adds 0.38 percent in 2020 to real consumption in the basin; second, there are small terms-of-trade gains in the basin as a consequence of the policy. This annuity is equivalent to 0.25 percent of aggregate consumption in 2029. The terms-of-trade impact means that even without compensation, the loss in aggregate consumption would be a smaller percentage than the loss in basin-wide real GDP.

At the sectoral level, there are two broad types of factor adjustment. First, as water becomes scarcer, there is a fall in the number of hectares of irrigable land[2] used in irrigation production, as some irrigable land moves to dry-land production (see Figure 7). Other farm factors follow into dry-land production. Dairy cattle water usage falls by 40.8 percent by 2029 relative to the baseline, yet dairy output falls by only 7.3 percent, as dairy production moves from irrigated to dry-land technologies. A second type of adjustment concerns farm factor substitution. As the price of water rises relative to other farm outputs, farmers use water more sparingly by substituting other factors for water. In the case of rice production, water usage falls by 40.5 percent relative to the baseline by 2029, yet rice output falls by only 24.2 percent, reflecting substitution away from water. A consequence of these forms of adjustment is that the impact of fully implemented SDLs on basin-wide farm output is much smaller than we would infer from a database weight calculation. Such a calculation indicates that in 2029, basin-wide

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[1] Throughout this study, "baseline" refers to the underlying forecast which includes farm productivity growth and water-saving technological change over time.

[2] Irrigable land can be used for either irrigation or dry-land activities. Dry land is only used in dry-land activities.

farm output should fall by 9.2 percent as a consequence of fully implemented SDLs. This contrasts with the modelled fall in farm output of only 1.1 percent. Crude database calculations are included in the Tables 3 and 11 of this report as a starting point for estimating regional impacts. However, any farm factor movements greatly diminish the estimated income losses.

Similarly, a crude calculation based on database weights indicates that basin-wide real GDP should fall by 1.0 percent in 2029 relative to base, yet the modelled fall is only 0.29 percent.

Two different regional representations are reported in this study. Farm income, real GDP, employment and household consumption are reported by statistical sub-division in Table 3. Modelled outcomes are reported underneath outcomes derived from crude database calculations. This table also reports net water trades in the regions of the southern basin, where inter-regional water trading is possible. Water trading is permissible between irrigators in the northern basin, but not between users. Water movements play an important part in the adjustment process. A second representation uses NRM regions to report macro and industry level results (Tables 4 to 7).

In looking at regional impacts, we need to remember that farmers, especially in the southern basin, are both producers and water traders. In the Lower Murrumbidgee and Murray NSW regions, there are substantial falls in rentals to irrigable land. These declines are offset by substantial increases in the price of water held by irrigators in these regions. Even though farm income falls in these two and indeed all basin regions relative to the baseline, water sales to the Commonwealth at least offset these losses. Such sales are treated as an annuity rather than a source of farm income within TERM-H2O.

The main surprise at the sectoral level is that vegetables output across the basin increases relative to the baseline. This is because the falling price of land more than offsets the rising price of water in the altered costs of the vegetables sector. Vegetables entail a relatively high land cost share and a relatively low water cost share in production. Cereals (non-rice) output rises slightly relatively to the baseline, taking advantage of increased availability of land for dry-land production. Most non-rice cereals produced in the basin rely on dry-land rather than irrigated technologies, so the impact of reduced irrigated cereals production on overall cereals output is small.

National real GDP which reflects the lost value of water otherwise used in economic activity is -0.013 percent relative to the baseline in 2029.

A scenario variant

In a variant on the main scenario, all proceeds from water sales exit the basin. Although this changes the sign on the outcome for real consumption across the basin, the difference is not dramatic. By 2029, real consumption falls by 0.17 percent instead of increasing by 0.14 percent relative to the baseline. Job losses by 2029 relative to base are around 1000 instead of 600. Basin-wide real GDP falls slightly relative to the main scenario.

Impacts of infrastructure upgrades

A final scenario models both fully compensated buybacks and infrastructure upgrades. Buybacks sales by July 2011 amounted to nearly 1100 GL, with an average annual expected allocation of 790 GL[3]. These cost almost $1.7 billion. Using past asset values as a guide, fully

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[3] Restoring the Balance volumes are updated regularly at http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/2008-09.html.

implemented buybacks of 2800 GL may cost in excess of $4.0 billion. This contrasts with infrastructure upgrades, which are expected to cost $4.6 billion across the basin and result in additional water available to farmers of around 240 GL, with around 570 GL available to the environment. In terms of value for money, purchasing water from farmers appears to be superior, even after allowing for the higher security of additional water arising from infrastructure upgrades.

From the perspective of farm output, the gains we estimate from a simple database calculation are much larger than modelled gains. A database calculation indicates that in 2020, fully implemented SDLs plus infrastructure upgrades reduce basin farm output by 6.8 percent instead of 9.3 percent, a boost of 2.5 percent in basin farm output relative to no upgrades. But the modelled outcome is for a reduction in farm output of 0.7 percent compared with 1.1 percent without the upgrades, a boost of only 0.4 percent. The apparent gain from infrastructure upgrades is much smaller once we include in the model farmer responses to water scarcity such as movements to dry-land production.

However, during years of drought, the marginal benefits of infrastructure upgrades will increase for two reasons. First, the price of water rises substantially during drought so that additional water becomes increasingly valuable. Second, if water from infrastructure upgrades is of very high security, then its availability will fall by a smaller proportion than irrigation water overall during drought. In part, therefore, some infrastructure upgrades may be justifiable as a form of drought insurance.

National real GDP reflects a slightly worse outcome than buybacks alone, being activity is 0.0155 percent below the baseline in 2029.

Summary of main results basin-wide

Macro results (% change relative to baseline)

	Buybacks 2800 GL—2020	Buybacks 2020 –less buybacks to date	Buybacks + upgrades 2020	Buybacks + upgrades less buybacks to date 2020
Water use	-26	-17	-21	-12
Land use	0	0	0	0
Dry-land output	3.1	2.0	2.0	1.1
Irrigation output	-6.4	-4.2	-4.1	-2.3
Real basin GRP	-0.18	-0.16	-0.05	-0.02
GVIAP contribution	*-0.33*	*-0.22*	*-0.21*	*-0.13*
Dry-land contribution	*0.22*	*0.14*	*0.14*	*0.08*
Employment	-0.02	-0.10	0.23	-0.02
Household consumption	0.34	0.15	0.42	0.18
Investment	-0.28	-0.25	-0.07	-1.42
Annuity as % of basin consumption	0.38	0.12	0.38	0.12
National real GDP	-0.0114	-0.0096	-0.0155	-0.0140

Macro results 2400 GL and 3200 GL scenarios (% change relative to baseline)

	Buybacks 2400 GL—2020	Buybacks + upgrades 2400 GL—2020	Buybacks 3200 GL—2020	Buybacks + upgrades 3200 GL—2020
Water use	-23	-18	-30	-25
Land use	0	0	0	0
Irrigation output	2.7	1.7	3.5	2.5
Dry-land output	-5.4	-3.4	-7.3	-5.3
Real basin GRP	-0.14	-0.03	-0.21	-0.09
GVIAP contribution	*-0.29*	*-0.17*	*-0.37*	*-0.25*
Dry-land contribution	*0.19*	*0.11*	*0.25*	*0.17*
Employment	-0.01	0.24	-0.02	0.22
Household consumption	0.32	0.39	0.37	0.45
Investment	-0.22	-0.03	-0.32	-0.12
Annuity as % of basin consumption	0.30	0.30	0.47	0.47
National real GDP	-0.0095	-0.0137	-0.0137	-0.0180

The marginal impact of additional water

Appendix 3 reports on a regression of available data on irrigation water prices in the southern basin against explanatory variables, including irrigation water availability, drought and output prices. The price of water changes much more in response to drought than changes in irrigation water availability. It is also sensitive to movements in a farm producer price index.

1. The main scenario

The scenario entails 2800 GL of permanent water entitlements in the Murray-Darling Basin (MDB) being purchased from farmers by the Commonwealth by 2019. This includes the purchases that had taken place by July 2011, which amounted to around 1100 GL.[4] 2800 GL is equal to around 26 percent of average allocated water across the basin.

TERM-H2O is a dynamic model, meaning that we can ascribe water purchases year by year to the model. In addition, since the purchases entail full compensation to farmers at market prices, we include the compensation in the model.

1.1 Analysing the impacts of water buybacks in the MDB

Explaining basin impacts using database weights alone

In the main scenario, by 2019, farmers have sold permanent entitlements equal to 26 percent of pre-buyback entitlements across the MDB. Using database weights, we can calculate a crude estimate of the impact on farm output. Irrigation accounts for 43 percent of farm output in the MDB in the TERM-H2O database in 2020. If we assume that removing 26 percent of water reduces irrigation output by 26 percent, and there are no other effects, we would conclude that farm output in the basin would fall by 11.3 percent (=-0.26 x 43%). But this is wrong for three reasons.

Why calculations based on database weights will overestimate impacts

First, irrigation water is not the sole source of water used in irrigation activities.[5] If we calculate the volume sold as a share of entitlements plus effective rainfall, the reduction in water supply shrinks to 21 percent from 26 percent. This reduces the estimated loss in farm output from 11.3 percent to 9.3 percent.

A second and more important problem with the crude estimate is the underlying assumption that farmers put non-water inputs used in irrigation activity to no other use when less water is available. This is contrary to the evidence. With a reduction in water availability, farmers switch their land and other farm factors from irrigated activities to dry-land activities. This is particularly evident for dairy. For example, as shown in Table 2, the reduction in water availability and consequent increase in the price of water in 2007-08 compared with 2005-06 led to a reduction in water used in dairying of 65 percent, to 458 GL from 1287 GL. The corresponding reduction in dairy output was only 26 percent. This reflected a shift of farm factors from irrigated dairy production to dry-land dairy production with increased reliance on hand-feeding. Water was so expensive in 2007-08 that dairy farmers profited from selling water and buying fodder.

A third effect captured in TERM-H2O concerns substitution. By increasing the price of water, buybacks lead farmers to operate with higher usage of non-water factors in each unit of farm output. For example, with a higher price for water, vegetable farmers substitute capital

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[4] The estimated water accounts for usage and allocations in the MDB vary between authorities. For example, the estimates provided by the National Water Commission are higher than the water accounts published by the ABS. For this reason, we convert nominal volumetric targets to percentages.

[5] Rice uses 12 to 14 ML per hectare so the contribution of rainfall to total water requirements is small. Dairy production uses between 3 and 5 ML per hectare and grapes around 5 ML per hectare. For these activities, rainfall makes a significant contribution in an average year (given that 2 ML per hectare is equivalent to 200 mm of effective rainfall).

(e.g., updated irrigation equipment) and labour (e.g., more rigorous checking for water leaks) for water.

Taking these three effects into account, TERM-H2O projects the outcome of a 26 percent buyback scheme as a 0.9 percent reduction in farm output, not an 11.3 percent reduction as in the initial crude estimate, by 2020.

Are modelled resource movements consistent with observation?

TERM-H2O modelling shows that as water availability falls and its price rises, farmers switch in part to dry-land farming. They also substitute other factors for water in irrigation sectors. Keeping in mind that the 2800 GL target is reached by 2019, four sectors experience cuts in water usage of more than 30 percent by 2020 relative to the baseline: namely cereals, rice, dairy cattle and other livestock.

Table 1: Modelled change in basin-wide farm output and water, 2020 and 2029
(% change relative to baseline)

	Output 2020	Water 2020	Output 2029	Water 2029
Cereal	2.3	-50.3	2.5	-42.3
Rice	-21.4	-36.2	-24.2	-40.5
DairyCattle	-5.3	-32.3	-7.3	-40.8
OthLivestock	0.6	-43.7	0.0	-41.5
Cotton	-5.7	-10.4	-3.4	-9.6
Grapes	-3.6	-13.6	-4.7	-15.2
Vegetables	5.2	11.4	6.8	16.7
Fruit	0.4	-0.8	1.0	1.1
OtherAgriclt	0.8	-5.5	1.2	-3.5

In the case of cereals, output rises slightly relative to the baseline. This reflects a movement of farm factors (i..e, mobile capital and owner-operator inputs) towards dry-land cereals in response to reduced irrigation water availability. In the case of rice, although water usage drops by 36.2 percent in 2020 relative to the baseline, output drops by only 21.4 percent. The dominant reason is substitution of relatively cheaper non-water factors for water in rice production. Dairy production provides a different story. During the drought of the previous decade, dairy producers coped with much more expensive water by selling part of their drought-diminished allocations; dairy farmers reduced or suspended irrigated grazing, and used part of the proceeds from water sales to purchase fodder. In Table 2, we see that recorded dairy output in 2007-08 was 26.5 percent lower than in 2005-06 at the same time as water usage fell by 64.4 percent. The modelled impact of fully implemented SDLs is for a relatively modest movement away from irrigated production towards dry-land production with increased hand-feeding. Modelled dairy water usage falls by 32.3 percent relative to the baseline, yet dairy output declines by only 5.3 percent (Table 1). The story for other livestock production is similar to that of non-rice cereal production: the sector is dominated by dry-land rather than irrigated production and receives a small boost in output through the movement of farm factors from irrigated to dry-land activities.

Table 2: Observed change in basin-wide farm output and water, 2007-08 relative to 2005-06 (% change)

	Output	Water
Cereal	-45.8	-9.9[a]
Rice	-98.2	-97.8
DairyCattle	-26.5	-64.4
OthLivestock	-1.2	-70.6[a]
Grapes	2.7	-15.7
Vegetables	9.3	-13.7
Fruit	21.8	-18.4

Source: ABS catalogue no. 7125.0 ; Anderson et al. (2010); ABARES (2010).

a. Cereals and other livestock are predominantly dry-land activities

Farmers are compensated at market prices

Yet this is not the end of the story. Farmers are being compensated at market prices for buyback water. We can treat buyback proceeds as an annuity that either adds to household spending or farm investment. This in turn has a positive marginal impact on regional employment. If we assume that all the proceeds of buybacks stay within the basin, basin-wide aggregate consumption (the preferred measure of regional welfare) will rise relative to the baseline, despite basin-wide real GDP falling. This is because there are two sources of terms-of-trade gains.[6] The Commonwealth's involvement in the market raises the price of water, which in turn provides farmers with gains from water trading. Another terms-of-trade gain source concerns farm outputs. Since farm output declines slightly and we assume that demand curves for farm outputs are down-sloping, basin-wide farm output prices rise slightly with the implementation of SDLs.

If we assume that no proceeds stay within the basin, the basin-wide aggregate consumption will fall relative to the baseline, but by a smaller percentage than real GDP. The terms-of-trade gain from reduced farm outputs explains this smaller fall. Overall, the results do not hinge critically on the where buyback proceeds are spent. Even if all proceeds exit the basin, the impacts on the basin's economy are relatively small.

Macro impacts

Figure 1 shows the basin-wide macroeconomic impacts of 2800 GL being sold to the Commonwealth by 2019. Real GDP continues to fall slightly relative to the baseline in the decade after SDLs have been fully implemented (i.e, after 2019), ending up around 0.25 percent below base, but still a much smaller outcome than the 1.2 percent calculated for 2029 using database weights (Table 3, row (12)). Household consumption rises relative to the baseline, albeit slightly, due to terms-of-trade gains from selling water to the Commonwealth. That real GDP continues to decline relative to base once SDLs are fully in place is a

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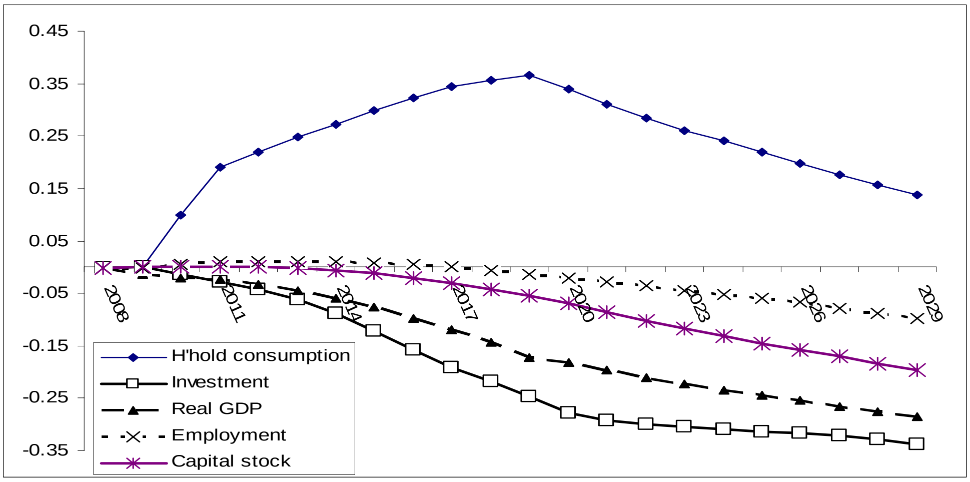
[6] At a national level, "terms-of-trade" refers to the price of exports divided by the price of imports. At regional level, they refer to the price of international plus inter-regional exports divided by the price of international plus inter-regional imports, and include water trading. GDP or regional incomes includes exports but not imports. Household consumption includes imports but not exports. Therefore, as the terms-of-trade increase (i.e, the price of exports rises relative to the price of imports), real household consumption rises relative to real income, be that at the national or regional level.

consequence of regional aggregate investment persisting below the baseline. This lowers capital stocks relative to the baseline gradually, and in turn drags down employment slightly. Therefore, with factors of production declining over time relative to the baseline, real GDP also falls.

Figure 1: Macroeconomic impacts, MDB

% change from the baseline



At the national level, real GDP falls relatively to the baseline as water is removed from production. By 2029, real GDP is 0.028 percent below the baseline.

Table 3 shows the impacts of fully implemented SDLs in 2020 and 2029 relative to the baseline. In all regions, the modelled impact of SDLs on farm output is much smaller than the output loss derived from a database calculation. Factor mobility, facilitated substantially by water trading, accounts for the difference. Water trading provides farmers with a potential additional source of income. Murray NSW is the largest exporter of water to other regions (110.3 GL, Table 3, row (7)). The price is $114 per ML in 2020 (2008 dollars). This indicates that net water exports add $12.6 million (=114/1000 x 110.3) to the region's income. This is counted in real GDP (row (2)) but not farm income (row (1)). In addition, sales of permanent water to the Commonwealth add an annuity to the region's spending base. Row (5) of Table 3 gives us an approximate idea of the sensitivity of results to the proportion of buyback proceeds that stay in the region. Lower Murrumbidgee's annuities as a share of aggregate consumption are the largest in the basin, 1.5 percent in 2020 (Table 3, row (5)). In Murray NSW, the annuity from sales to the Commonwealth is 1.1 percent of aggregate household spending in 2020.

By 2029, basin-wide employment has fallen by 0.1 percent or around 600 jobs relative to the baseline.

Table 3: Comparing database calculations to modelled impacts in 2020 and 2029 (% change relative to base)

Year 2020	Basin-wide MDB	TmwthNSlpNSW	NCentralNSW	MacquarieNSW	McqrieBarNSW	UpDarlingNSW	CntralWstNSW	LachlanNSW	WagCntMrmNSW	LMrmbNSW	MurrayNSW	MrryDrlngNSW	MalleeVic	LoddonVic	GoulburnVic	OvnsMurryVic	DrlngDwnsQld	SouthWQld	MurrayLndsSA
Model																			
(1) Farm income (%)	-0.89	-0.2	-0.5	-0.3	-0.5	-1.2	-0.4	-0.3	-0.8	-1.3	-3.5	-0.6	-0.7	-0.9	-1.2	-1.2	-0.8	-0.6	-0.6
(2) Real GDP (%)	-0.18	0.0	-0.1	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.4	-0.3	-0.1	-0.3	-0.1	-0.4	-0.2	-0.3
(3) Employment (%)	-0.02	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	-0.1	-0.1	0.0	-0.1	0.0	-0.2	-0.1	-0.1
(4) Household consumption (%)	0.34	0.1	1.5	0.1	0.8	0.7	0.1	0.3	0.1	1.9	0.9	0.1	0.7	0.0	0.3	0.2	0.1	0.3	0.4
(5) Annuity: % of consumption	0.38	0.1	0.7	0.1	0.6	0.5	0.1	0.3	0.2	1.5	1.1	0.4	0.9	0.1	0.5	0.2	0.3	0.3	0.6
(6)Terms of trade[a]	0.27	0.1	2.0	0.1	0.7	0.7	0.0	0.1	0.1	1.1	0.3	0.4	0.5	0.0	0.3	0.1	0.5	0.6	0.3
(7) Net water trade (GL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.2	-16.1	110.3	-17.1	-32.7	11.4	-100.5	12.6	0.0	0.0	-46.0
Database calc.																			
(8) Farm income (%)	*-9.3*	*-1.9*	*-4.9*	*-3.3*	*-3.9*	*-6.6*	*-4.4*	*-2.4*	*-5.2*	*-15.3*	*-17.0*	*-25.6*	*-13.7*	*-9.0*	*-17.0*	*-8.3*	*-6.5*	*-3.5*	*-16.2*
(9) Real GDP (%)	*-0.9*	*-0.1*	*-1.0*	*-0.1*	*-0.4*	*-0.5*	*-0.1*	*-0.1*	*-0.2*	*-3.1*	*-1.7*	*-4.4*	*-2.0*	*-0.2*	*-1.5*	*-0.3*	*-0.9*	*-0.3*	*-3.2*
(10) Employment (%)	*-0.9*	*-0.1*	*-1.0*	*-0.1*	*-0.4*	*-0.5*	*-0.1*	*-0.1*	*-0.2*	*-3.1*	*-1.7*	*-4.4*	*-2.0*	*-0.2*	*-1.5*	*-0.3*	*-0.9*	*-0.3*	*-3.2*
(11) Household consumption (%)	*-0.9*	*-0.1*	*-1.0*	*-0.1*	*-0.4*	*-0.5*	*-0.1*	*-0.1*	*-0.2*	*-3.1*	*-1.7*	*-4.4*	*-2.0*	*-0.2*	*-1.5*	*-0.3*	*-0.9*	*-0.3*	*-3.2*
Year 2029																			
Model																			
(12) Farm income (%)	-1.07	-0.3	-0.5	-0.5	-0.8	-1.6	-0.4	-0.2	-0.9	-0.6	-3.5	-0.6	-0.7	-1.2	-1.6	-1.8	-1.3	-1.1	-0.8
(13) Real GDP (%)	-0.29	0.0	-0.4	-0.1	-0.3	0.0	0.0	0.0	-0.2	0.1	-0.5	-0.4	-0.4	-0.1	-0.5	-0.2	-0.7	-0.4	-0.4
(14) Employment (%)	-0.10	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.6	0.0	-0.1	-0.1	-0.1	-0.2	-0.1	-0.5	-0.3	-0.2
(15) Household consumption (%)	0.14	0.1	1.2	0.1	0.5	0.6	0.0	0.2	0.0	1.7	0.4	-0.1	0.4	-0.1	0.0	0.0	-0.2	0.1	0.1
(16) Annuity: % of consumption	0.25	0.1	0.4	0.1	0.4	0.3	0.0	0.2	0.1	1.0	0.7	0.3	0.6	0.0	0.3	0.1	0.1	0.2	0.4
(17) Terms of trade[a]	0.33	0.1	2.6	0.1	0.9	0.8	0.0	0.0	0.1	1.2	0.3	0.5	0.6	0.0	0.3	0.1	0.6	0.8	0.4
(18) Net water trade (GL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.3	-33.8	45.8	-16.8	-21.2	18.6	-70.4	19.4	0.0	0.0	-36.8
Database calc.																			
(19) Farm income (%)	*-9.2*	*-2.2*	*-5.7*	*-3.7*	*-5.0*	*-7.6*	*-4.4*	*-2.4*	*-5.2*	*-15.2*	*-16.9*	*-25.3*	*-13.2*	*-8.9*	*-16.6*	*-8.3*	*-7.3*	*-4.4*	*-15.9*
(20) Real GDP (%)	*-1.0*	*-0.1*	*-1.6*	*-0.2*	*-0.8*	*-0.9*	*-0.1*	*-0.1*	*-0.2*	*-3.2*	*-1.8*	*-4.5*	*-1.9*	*-0.2*	*-1.4*	*-0.3*	*-1.1*	*-0.4*	*-3.2*
(21) Employment (%)	*-1.0*	*-0.1*	*-1.6*	*-0.2*	*-0.8*	*-0.9*	*-0.1*	*-0.1*	*-0.2*	*-3.2*	*-1.8*	*-4.5*	*-1.9*	*-0.2*	*-1.4*	*-0.3*	*-1.1*	*-0.4*	*-3.2*
(22) Household consumption (%)	*-1.0*	*-0.1*	*-1.6*	*-0.2*	*-0.8*	*-0.9*	*-0.1*	*-0.1*	*-0.2*	*-3.2*	*-1.8*	*-4.5*	*-1.9*	*-0.2*	*-1.4*	*-0.3*	*-1.1*	*-0.4*	*-3.2*

a Weighted using aggregate consumption(C), using the formula $(p_x-p_m)*X/C$ where p_x and p_m are the percentage changes in import and export price indexes, and X aggregate exports (international + inter-regional).

Rows (6) and (17) of Table 3 provide a calculation of the regional terms-of-trade impacts as a share of aggregate consumption (see the footnote to Table 3). In the case of Lower Murrumbidgee and North Central NSW, the terms-of-trade gains in the scenario are sufficiently large (equivalent to a boost to aggregation consumption of 1.1% and 2.0% respectively in 2020) that aggregate consumption could increase relative to the baseline even without the proceeds of environmental sales remaining in the basin.

Why crude multiplier analysis is invalid

Some lobbyists estimate the regional impact of a policy as the direct impact multiplied by some arbitrary number, possibly 3.0 or more. This approach is invalid for two reasons. First, as we have already established, farmers move factors of production to other uses when less water is available for irrigation production. In a voluntary process, there is no logic in the notion that farmers would willingly sell water, then not put farm factors to other uses and as a consequence wear a loss. In a case of factor rigidity, such as irrigated perennials with minimum water requirements each year, either farmers who wish to retain their current area of plantings will not sell water at all, or they will only sell in line with realized water savings over time.

A second objection to crude multiplier analysis concerns a point that lobbyists often raise. A regional economic downturn will be accompanied by a downturn in regional house prices. Any regional price adjustments that occur will diminish the size of the multipliers. These multipliers have been derived from input-output analysis. Input-output models solve only for quantities or for prices, but not both at the same time. In a CGE model, which includes simultaneous price and quantity adjustments, regional multipliers are much smaller in the short run. In the case of housing, all the adjustment is borne by prices in the short run. Over a number of years, through a gradual decline in investment relative to the baseline, there may be an enlargement in initial impacts, as is evident for basin-wide real GDP and employment (Figure 1). However, a CGE model includes factor substitution possibilities that, in the short run, diminish rather than enlarge the impact of reduced water availability.

The first application of input-output analysis was by Wassily Leontief using the world’s first computer around 1940. At the time, the United States was in a deep depression with very high unemployment and idle factories. Leontief’s experiment was to estimate the impact of mobilizing idle productive resources for the US war effort. Given the unusual circumstance of a deep depression, the multiplier impacts that arose from this analysis were valid. With unemployed workers returning to work and resuming more usual spending patterns as pay packets came in, such analysis was relevant.

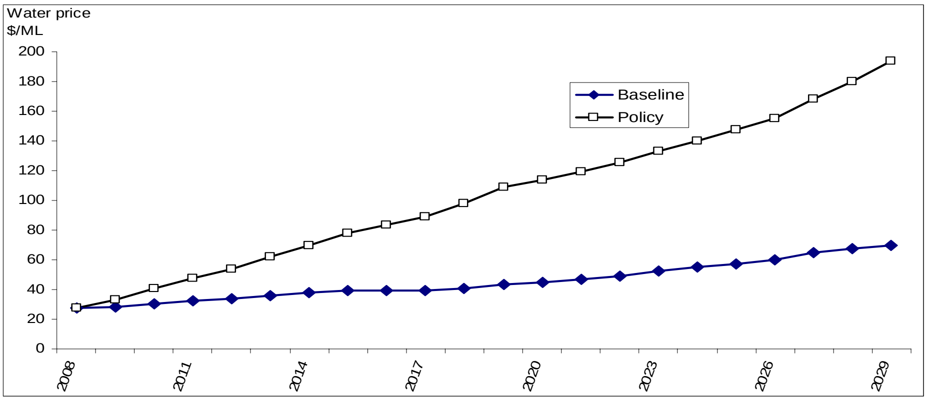
When analysts repeat Leontief’s methodology (or at least infer a multiplier from it) in an economy in which capital is at usual utilization levels and unemployment is low, they will almost certainly overestimate the impacts of an initial stimulus. When the economy is operating at or near full capacity, there is substantial competition for productive resources. When multiplier analysis is misused in this way, it becomes an instrument of rent-seeking rather than objective analysis.

Differences in the impact on factor prices

Next, we examine the impacts of SDLs on farm factor prices. Armed with an understanding of different impacts, we will be able to explain differences in outcomes between regions.

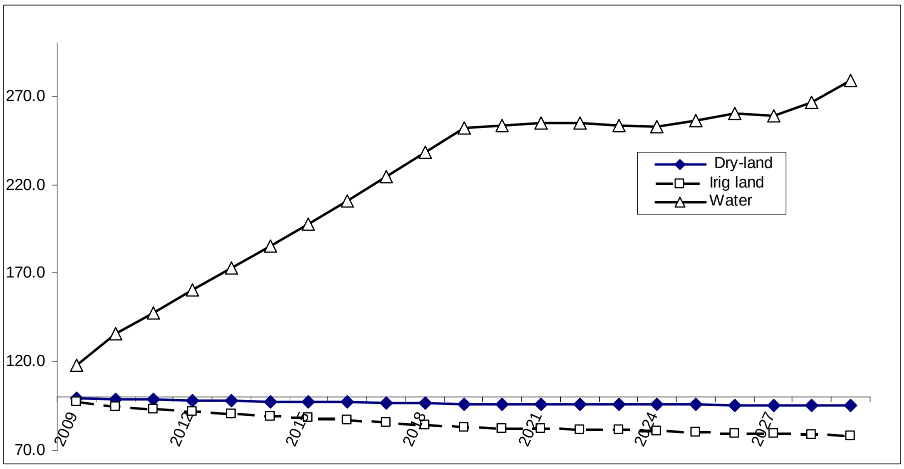
Since there is a permanent shift in the supply of water used in basin irrigation in the buyback scenario, there is a permanent hike in the price of water (Figure 2).

Figure 2: Average basin water price (2008 dollars)



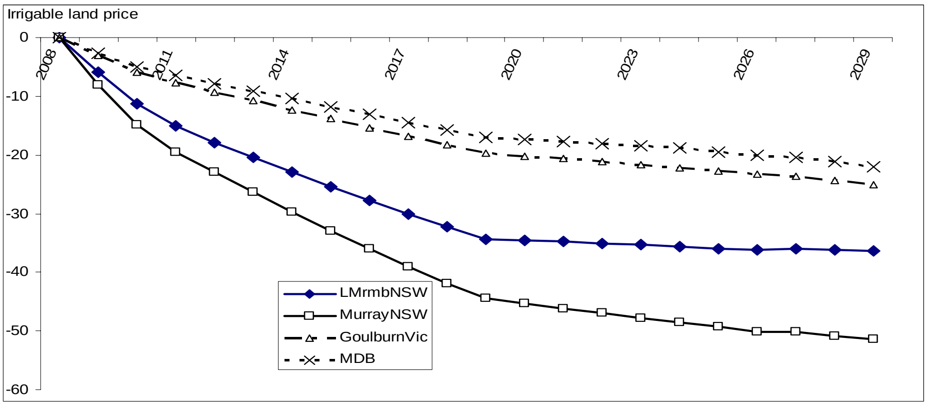
Fixed or sluggishly adjusting factors that are used with water will suffer a fall in rental relative to the baseline (i.e., factor price ratios will fall as factor use ratios rise, induced by the rising price of water).

Figure 3: Land rentals and water price, baseline=100



Since irrigable land can move to dry-land use as water availability falls, the quantity of land used for dry-land production increases, which also drives down dry-land rentals (Figure 3).

Figure 4: Price of irrigable land, selected regions % change relative to the baseline



The ratio of water (annual value) to irrigable land rentals varies between regions within the basin. The regions most vulnerable to a collapse in irrigable land rentals will be those without opportunities for farm factors to move into dry-land activity. Murray NSW and Murrumbidgee NSW both suffer relative large declines in irrigable land rentals as less water becomes available for irrigation production (Figure 4). Appendix 2 (Figure A.2) explains how the collapse in land rentals affects the output of grapes in these two regions. Unlike the other regions, these two regions have an increase in grapes output relative to base.

Why dry-land output increases

The costs of dry-land production fall relative to those of irrigation production. We can infer that is consistent with the change in relative costs. Figure 2 shows us that the price of water rises, which raises the costs of irrigation production. Figure 3 shows us that the price of land falls, which lowers the costs of dry-land production. Therefore, the costs of dry-land production fall relative to irrigable production. There is a movement of irrigable land into dry-land production as water is removed from irrigation production. Although aggregate farm output in the basin falls, the direct impact of lost irrigation output is partly offset by increased dry-land output (Figure 6).

Figure 5: Basin farm output costs, % change relative to the baseline

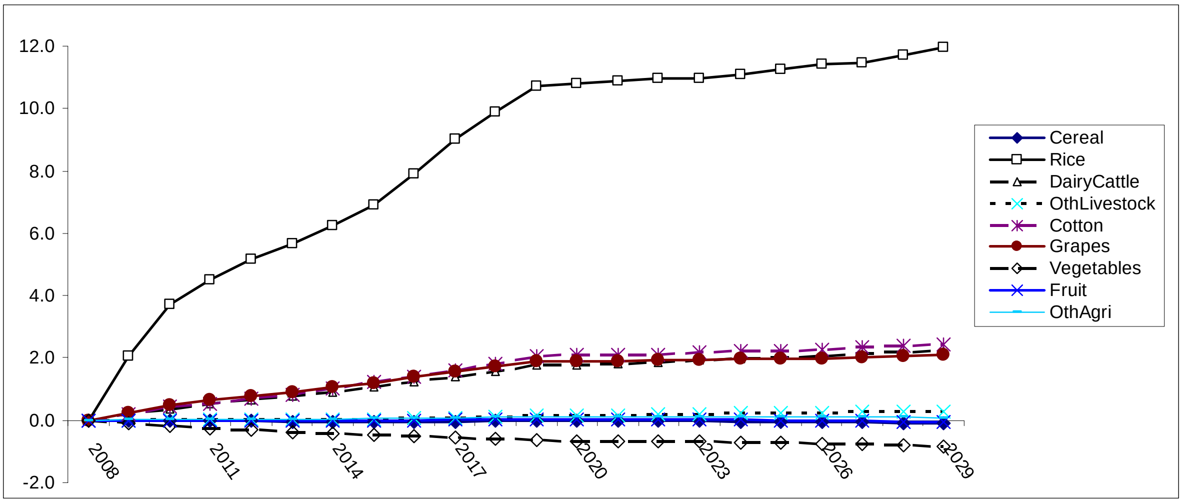
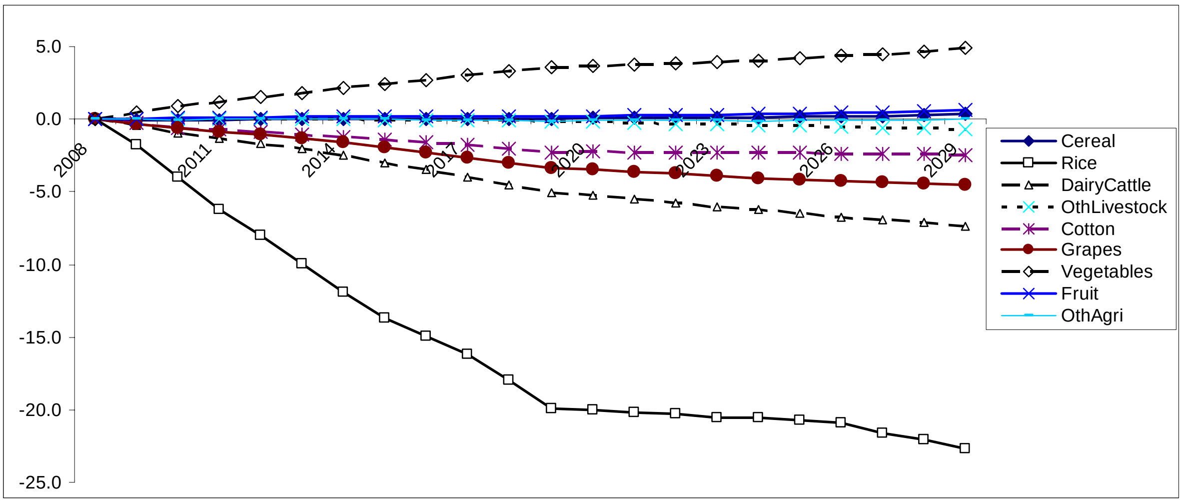


Figure 6: **Basin farm outputs**, % change relative to the baseline



Sector by sector overview

Dixon *et al.* (2011) contains a detailed explanation of how modelled percentage changes in output and year for each farm sector by region relate to changes in relative costs (also see appendix 2). We can summarise key findings from the Dixon et al. approach by using the extreme basin examples at the sectoral level, vegetables and rice. Basin-wide output of vegetables increases, while output of cereal, other livestock and fruit barely changes relative to the baseline. Rice suffers the largest fall in output relative to the baseline (Figure 6).

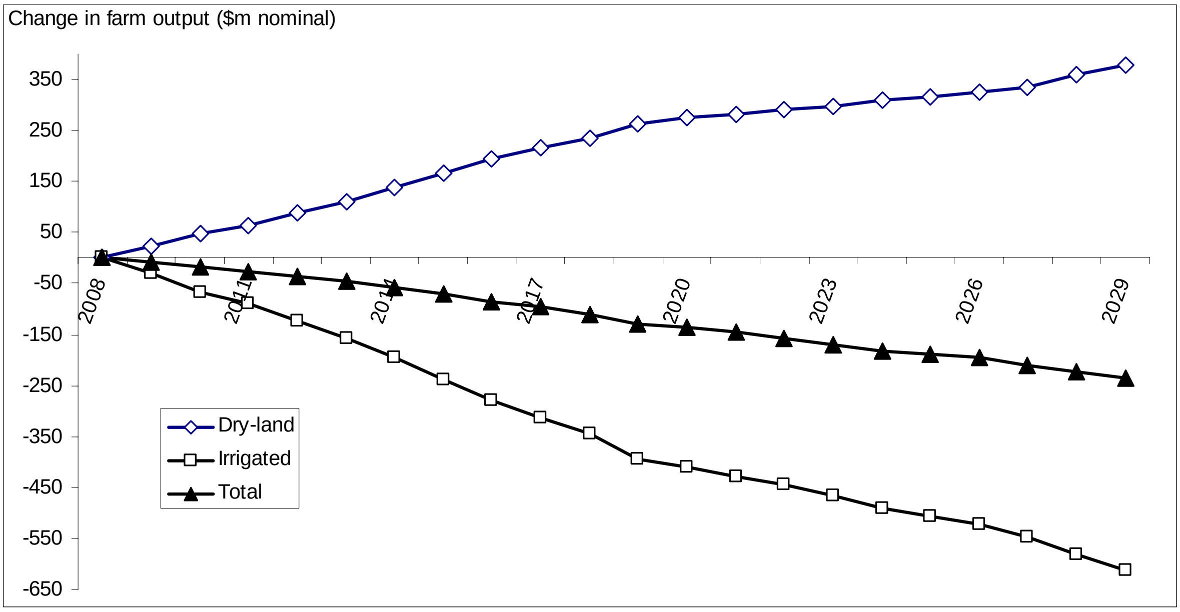
A superficial explanation is sufficient to explain why rice has the largest loss in output across the basin relative to the baseline. Since water accounts for a large share of rice production, its costs of production rise more than for other farm outputs in the basin (Figure 3.3). Therefore, as water moves to other activities with larger average products of water, output of rice falls.

For vegetables, it is not sufficient to explain the relatively favorable outcome as being due to the sector having a relatively low water cost share. Production costs of vegetables entail a relatively high irrigable land input share. The overall costs for vegetables fall (as shown in Figure 4) relative to the baseline: the falling rental on irrigable land more than offsets the rising price of water. For fruit, a predominantly irrigated activity, cheaper land also offsets more expensive water. We can think of fruit in a given orchard as comprising dry-land activity for part of the year, and irrigated for much of the year. More expensive water induces a small movement towards increased dry-land production during the year, with greater water-saving effort allowing a reduction in irrigated activity. In the case of cereals, the explanation is relatively straightforward. Non-rice cereals are predominantly dry-land: an increase in land available for dry-land production induces an increase in dry-land cereal activity, which more than offsets losses in irrigated cereal output. For both other livestock and dairy production, there is a movement towards increased dry-land activity as the price of water rises. In the case of predominantly dry-land other livestock production, increased dry-land activity is sufficient to offset losses in irrigated output.

Differences in short-run and long-run adjustments – time paths

If we look at the time path for rice and grapes in Figure 6, we see that for rice, there is a rapid decline in output relative to the baseline. Once SDLs are fully implemented in 2019, the rapid decrease stops. This is because rice uses relatively mobile inputs in production that allow rapid short-term adjustment, as is reflected in year-by-year water accounts (see Table 2). Grapes follow a different pattern: reduced water availability reduces rates of return on fixed capital (i.e., vineyards) in the sector, which reduces investment relative to the baseline. The adjustment over time is slower. Even after SDLs are fully implemented, grapes output continues to decline relative to base as fixed capital gradually diminishes.

Figure 7: MDB-wide output, $m change relative to the baseline



The switch from irrigated to dry-land output

Figure 7 shows that reduced irrigation output in the basin is offset partly by increased dry-land output. This adjustment is most obvious in observed data for dairy cattle (Table 2): dairy cattle are quite mobile between irrigated and dry-land production mixes.

1.2 Regional details

Methodology

The unique combination of bottom-up small region detail in TERM-H2O and a full CGE representation is limited to basin catchment statistical sub-divisions. However, there is interest in results at the natural resource management (NRM) level. In order to provide these, TERM-H2O includes a top-down representation of statistical local areas (SLAs). SLAs are mapped to NRM regions in order to provide estimates of NRM-level impacts. The most obvious limitation of this methodology is that irrigation water reduction shocks are imposed at the statistical sub-division level. The impacts of these shocks are allocated to NRM regions on the basis of estimated NRM irrigation activities, rather than directly.

The standout macro result from NRM representation is that a substantial proportion of modelled job losses across the basin arise in Condamine-Balonne. The employment impact in 2020, a year after full SDL targets have been attained, is several-fold smaller than that in 2029. A gradual decline in farm investment relative to the baseline over time explains the gradual worsening decline. However, the employment impacts even in Condamine-Balonne are not dramatic. Job losses in Condamine-Balonne in 2020 are 65 jobs or 0.1 percent relative to the baseline. By 2029, jobs fall by almost 200 or 0.4 percent of the baseline workforce.

Table 4: NRM sectoral and macro outcomes relative to baseline, 2020

	DrylandAg	IrigAg	FoodDrinks	Textile	OthManuf	Mining OthPrimary	Utilities	Services	Real GDP	Aggregate consumption	Employment	Employment
	%	%	%	%	%	%	%	%	%	%	%	No.
Paroo	1.1	-10.4	-0.1	-0.2	-0.1	0.0	0.0	0.0	-0.09	0.31	0.0	0
Namoi	1.3	-2.1	-0.1	-1.0	0.0	0.0	0.0	0.0	0.01	0.35	0.0	11
Gwydir	2.1	-2.2	-0.1	-1.2	-0.2	0.0	0.0	0.1	0.17	1.14	0.2	13
Border	2.3	-3.9	-0.1	-1.2	-0.5	0.0	0.0	0.0	-0.20	0.27	-0.1	-16
Moonie	2.2	-6.3	-0.2	-1.3	-0.7	0.0	0.0	-0.1	-0.23	0.16	-0.2	-2
CondamBalone	2.0	-5.3	-0.1	-1.2	-0.3	0.0	0.0	-0.1	-0.21	0.19	-0.1	-65
Warrego	1.8	-5.4	-0.1	-1.4	-0.3	0.0	0.0	0.0	-0.09	0.38	0.0	-1
MacCastlr	1.2	-3.5	0.0	-0.9	0.0	0.0	0.0	0.0	-0.02	0.13	0.0	9
BarwonDarlng	3.0	-5.0	0.0	-1.4	-0.2	0.0	0.0	0.1	-0.01	0.72	0.0	1
Lachlan	0.8	-5.1	0.0	-0.2	-0.1	0.0	0.0	0.1	0.01	0.33	0.0	8
MrmbidgeeNSW	5.4	-7.2	-0.1	-0.2	0.0	0.0	0.1	0.1	0.10	0.66	0.1	66
MurrayNSW	13.2	-11.2	-0.2	-0.7	-0.1	0.0	0.0	0.1	0.02	0.89	0.0	22
LowerDarling	4.3	-2.2	-0.1	0.1	-0.2	0.0	0.0	0.0	-0.15	0.04	-0.1	-4
MurrayVic	4.2	-3.9	-0.2	-0.2	-0.1	0.0	0.0	0.0	-0.06	0.44	0.0	-23
WimmAvoca	3.8	-14.0	-0.1	0.0	-0.4	0.0	0.1	0.0	0.14	0.95	0.2	5
Loddon	3.1	-10.3	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.08	-0.02	0.0	-29
GoulbnBroken	5.1	-6.3	-0.5	0.0	-0.1	0.0	0.0	0.0	-0.13	0.33	-0.1	-55
Campaspe	5.8	-8.2	-0.5	0.0	-0.1	0.0	0.0	0.0	-0.20	0.26	-0.2	-24
Ovens	4.6	-8.4	-0.2	-0.2	0.0	0.0	0.0	0.0	-0.06	0.15	0.0	-7
MurraySA	3.0	-3.3	-0.2	0.0	0.0	0.0	0.0	0.0	-0.10	0.37	-0.1	-20
MDB total	5.2	-8.0	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.18	0.34	-0.02	-110

Table 5: NRM sectoral and macro outcomes relative to baseline, 2029

	DrylandAg	IrigAg	FoodDrinks	Textile	OthManuf	Mining OthPrimary	Utilities	Services	Real GDP	Aggregate consumption	Employment	Employment
	%	%	%	%	%	%	%	%	%	%	%	No.
Paroo	1.1	-13.2	-0.2	-0.5	-0.3	0.1	0.0	-0.2	-0.29	0.20	-0.2	-2
Namoi	1.6	-2.5	-0.1	-1.7	-0.1	0.1	0.0	0.0	-0.13	0.31	0.0	-10
Gwydir	2.9	-2.5	-0.1	-1.9	-0.4	0.0	0.0	0.0	-0.05	1.03	0.0	3
Border	2.4	-4.5	-0.2	-2.2	-1.2	0.1	-0.1	-0.3	-0.61	-0.07	-0.5	-53
Moonie	2.3	-6.4	-0.5	-2.3	-1.7	0.1	0.0	-0.3	-0.66	-0.18	-0.5	-5
CondamBalone	2.0	-5.8	-0.3	-2.2	-0.8	0.1	0.0	-0.3	-0.59	-0.11	-0.4	-197
Warrego	1.9	-5.8	-0.2	-2.1	-0.4	0.0	0.0	-0.1	-0.32	0.21	-0.2	-6
MacCastlr	1.3	-3.6	-0.1	-1.6	0.0	0.1	0.0	0.0	-0.07	0.10	0.0	0
BarwonDarlng	3.7	-5.2	0.0	-2.1	-0.3	0.1	0.0	0.0	-0.08	0.62	0.0	0
Lachlan	0.9	-4.7	0.0	-0.3	-0.1	0.1	0.0	0.1	-0.01	0.23	0.0	10
MrmbidgeeNSW	5.2	-6.3	-0.1	-0.4	0.1	0.0	0.2	0.1	0.12	0.54	0.2	105
MurrayNSW	10.0	-9.1	-0.3	-1.1	0.0	0.0	0.0	0.1	-0.09	0.36	0.0	-3
LowerDarling	4.3	-2.5	-0.2	0.1	-0.3	0.1	0.0	-0.1	-0.25	-0.17	-0.2	-6
MurrayVic	4.5	-4.6	-0.3	-0.3	-0.2	0.1	0.0	0.0	-0.17	0.17	-0.1	-63
WimmAvoca	3.9	-13.6	-0.2	0.0	-0.7	0.1	0.0	0.0	0.06	0.63	0.1	4
Loddon	2.9	-11.1	-0.2	-0.1	0.0	0.1	-0.1	0.0	-0.15	-0.11	-0.1	-55
GoulbnBroken	5.0	-7.2	-0.8	0.0	-0.1	0.0	-0.2	-0.1	-0.28	0.05	-0.2	-133
Campaspe	5.8	-9.8	-0.8	0.0	-0.2	0.1	-0.2	-0.1	-0.39	-0.06	-0.3	-46
Ovens	4.7	-9.8	-0.3	-0.4	0.0	0.0	-0.1	0.0	-0.17	-0.02	-0.1	-20
MurraySA	3.0	-4.0	-0.3	0.0	0.0	0.0	-0.1	-0.1	-0.23	0.06	-0.2	-48
MDB total	4.9	-8.4	-0.3	-0.1	0.0	0.1	0.0	0.0	-0.29	0.14	-0.10	-600

Tables 6 and 7 report sectoral impacts. The main features of these two tables are:

- a substantial movement from irrigated towards dry-land technologies;
- relatively modest impacts on downstream and service sectors; and
- exceptions to the general pattern in the Murrumbidgee and Murray regions.

Appendix 2 goes into some detail on why these the Murrumbidgee and Murray regions are exceptions. As outlined above, there is a collapse in land rentals in these two regions. This enhances their competitiveness relative to other regions, resulting in increases in grapes, irrigated fruit and vegetables output. In the case of vegetables, basin-wide output increases as falling basin-wide land rentals lower the cost of vegetables production (Figures 5 and 6).

Table 6: NRM sectoral impact, 2020 (% change relative to baseline)

	Paroo	Namoi	Gwydir	Border	Moonie	CondamBalone	Warrego	MacCastlr	BarwonDarlng	Lachlan	MrmbidgeeNSW	MurrayNSW	LowerDarling	MurrayVic	WimmAvoca	Loddon	GoulbnBroken	Campaspe	Ovens	MurraySA	All MDB
CerealDryL	1.1	0.8	1.3	1.9	2.0	1.8	1.5	1.0	1.9	0.8	5.9	15.0	4.3	4.1	4.1	3.3	4.8	4.8	4.5	2.9	5.5
CerealIrig	-22.9	-14.7	-20.6	-27.4	-28.3	-27.1	-25.4	-17.5	-27.7	-11.2	-29.2	-17.4	-29.8	-28.7	-28.7	-32.6	-30.2	-30.2	-31.3	-28.5	-22.8
Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-25.2	-14.2	0.0	-27.7	0.0	0.0	-26.2	-26.2	0.0	0.0	-22.6
DairyCatDryL	0.0	5.0	0.0	0.0	0.0	7.8	0.0	6.4	0.0	5.4	14.1	17.6	0.0	12.2	0.0	11.2	13.2	13.2	12.2	11.2	13.0
DairyCatIrig	0.0	-2.9	0.0	0.0	0.0	-7.2	0.0	-4.6	0.0	-3.1	-14.3	-1.2	0.0	-10.0	-9.1	-11.3	-9.0	-9.0	-10.4	-9.4	-8.9
OthLivstoDry	1.1	0.8	1.0	1.8	1.9	1.7	1.2	1.2	2.5	0.8	4.2	13.0	3.6	3.8	3.2	2.8	4.1	4.1	4.0	2.6	4.4
OthLivstoIrg	-10.3	-6.6	-7.7	-12.9	-13.4	-12.4	-10.5	-7.5	-13.6	-5.0	-14.0	-26.0	-13.2	-15.3	-13.5	-18.0	-15.1	-15.1	-15.8	-14.8	-18.8
CottonDryL	0.0	8.0	8.3	8.4	8.5	7.8	10.0	7.4	10.0	7.3	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.5
CottonIrig	-2.0	-1.2	-1.6	-3.6	-4.2	-3.2	-4.3	-0.6	-4.3	1.6	-7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.6
Grapes	-2.3	-0.2	0.0	-3.7	0.0	-2.6	-3.4	-1.3	-3.4	0.0	1.3	6.6	-3.7	-4.2	0.0	-7.0	-8.2	-8.2	-6.1	-4.1	-3.6
Vegetables	0.0	0.7	-0.4	0.7	0.0	0.7	0.0	0.6	0.0	0.2	13.6	23.9	5.2	3.9	0.0	1.9	5.0	5.0	3.7	3.2	5.2
FruitDryL	0.0	1.0	2.1	2.7	0.0	2.4	0.0	1.6	0.0	1.2	8.0	9.0	4.8	4.8	0.0	4.0	5.3	5.3	4.8	3.7	5.3
FruitIrig	-1.6	-0.9	-0.9	-1.7	0.0	-1.7	-0.7	-0.8	-0.7	-0.8	3.0	7.8	-0.2	-0.8	-0.8	-2.2	-0.5	-0.5	-1.3	-1.4	0.0
OthAgriDry	0.0	1.1	1.2	2.7	2.8	2.7	1.8	1.6	2.9	1.1	5.4	6.8	4.2	4.3	4.2	4.2	4.9	4.9	4.8	3.5	5.1
OthAgriIrig	0.0	-1.8	-2.0	-3.8	-4.0	-3.9	-3.5	-2.2	-3.8	-1.6	-1.6	9.1	-3.1	-3.7	-3.7	-5.4	-3.6	-3.6	-4.7	-4.3	-1.6
AgriSrvces	0.0	-0.3	-0.5	-0.8	-0.9	-0.9	-1.2	-0.3	-1.0	-0.4	-0.5	-0.6	-0.6	-0.9	-0.9	0.0	-0.9	-0.9	0.0	0.0	-0.8
GinnedCotton	0.0	-1.3	-1.3	-1.3	-1.3	-1.3	-1.4	-1.3	-1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.2
ForestFish	0.0	0.0	0.0	-0.2	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
Mining	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MeatProds	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.1	0.0	0.0	-0.6	0.0	0.0	0.0	-0.1	0.1	0.1	0.0	-0.1	-0.1
DairyProds	0.0	-0.2	0.0	-0.7	0.0	-0.7	0.0	-0.2	0.0	-0.6	-0.4	-0.3	0.0	-0.7	-1.1	-0.6	-1.2	-1.2	-0.7	-0.6	-0.9
FruitVeg	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OthFodTobDrk	-0.1	0.0	-0.1	-0.1	-0.2	-0.2	-0.1	0.0	-0.1	0.0	0.1	0.0	0.0	-0.1	-0.1	-0.1	-0.4	-0.4	-0.1	-0.1	-0.1
FlourCereals	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	-0.4	-0.5	0.0	-0.4	0.0	-0.2	-0.4	-0.4	-0.4	0.0	-0.4
WineSpirits	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	0.0	-0.2	0.0	-0.2	-0.3	0.0	-0.1	-0.2	-0.2	-0.2	-0.3	0.0
TCFs	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.2	-0.2	0.0	-0.2	-0.2	-0.7	0.1	-0.2	0.0	-0.1	0.0	0.0	-0.2	0.0	-0.2
WoodPaper	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
PrintPublish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
OthManufact	-0.1	0.0	-0.1	-0.2	-0.2	-0.2	-0.1	0.0	-0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ElectricGas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WaterDrains	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.2	0.0	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
OtherSrvces	0.0	0.0	0.1	0.0	-0.1	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7: NRM sectoral impact, 2029 (% change relative to baseline)

t	Paroo	Namoi	Gwydir	Border	Moonie	CondamBalone	Warrego	MacCastlr	BarwonDarlng	Lachlan	MrmbidgeeNSW	MurrayNSW	LowerDarling	MurrayVic	WimmAvoca	Loddon	GoulbnBroken	Campaspe	Ovens	MurraySA	All MDB
CerealDryL	0.9	1.2	2.5	2.2	2.1	1.9	1.8	1.1	2.9	0.9	5.8	12.1	4.4	4.4	4.5	3.3	4.5	4.5	4.2	3.1	5.3
CerealIrig	-35.7	-17.1	-22.4	-36.5	-38.3	-37.9	-39.4	-20.2	-42.3	-10.4	-28.2	-13.1	-28.7	-27.7	-27.6	-31.8	-29.6	-29.6	-31.1	-28.7	-20.3
Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-29.0	-14.0	0.0	-33.1	0.0	0.0	-31.2	-31.2	0.0	0.0	-25.8
DairyCatDryL	0.0	6.3	0.0	0.0	0.0	8.9	0.0	7.4	0.0	6.4	16.3	15.5	0.0	13.8	0.0	12.7	15.1	15.1	14.0	13.9	14.7
DairyCatIrig	0.0	-4.6	0.0	0.0	0.0	-11.9	0.0	-5.9	0.0	-3.1	-18.7	1.6	0.0	-13.1	-11.4	-14.6	-11.7	-11.7	-13.8	-13.0	-11.5
OthLivstoDry	1.1	1.0	1.3	1.8	1.9	1.7	1.2	1.2	3.0	0.9	3.9	9.3	3.3	3.8	2.9	2.5	4.0	4.0	4.1	2.6	4.0
OthLivstoIrg	-14.3	-7.8	-9.2	-15.9	-16.6	-15.9	-14.4	-7.9	-18.3	-4.3	-12.6	-26.0	-12.0	-15.3	-12.6	-17.6	-14.9	-14.9	-16.2	-15.3	-18.6
CottonDryL	0.0	6.3	6.6	6.0	5.8	5.3	8.2	5.4	8.2	5.4	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.8
CottonIrig	-2.8	-1.8	-2.2	-4.1	-4.6	-3.8	-4.7	-1.3	-4.7	1.5	-5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.1
Grapes	-4.7	-0.6	0.0	-6.9	0.0	-5.2	-5.0	-2.0	-5.0	0.0	2.7	12.4	-4.6	-5.4	0.0	-9.4	-11.3	-11.3	-8.4	-5.7	-4.7
Vegetables	0.0	7.2	-0.4	1.0	0.0	1.0	0.0	1.1	0.0	0.5	16.4	31.2	7.0	5.2	0.0	3.3	6.6	6.6	5.1	4.3	6.7
FruitDryL	0.0	1.2	2.5	3.4	0.0	2.9	0.0	1.7	0.0	1.3	8.6	8.7	5.3	5.8	0.0	4.5	5.8	5.8	5.2	4.3	5.9
FruitIrig	-2.8	-1.1	1.1	-2.9	0.0	-2.9	0.7	-0.8	0.7	-0.8	5.1	13.8	0.4	-0.5	-0.5	-2.5	-0.1	-0.1	-1.3	-1.6	0.5
OthAgriDry	0.0	0.9	1.0	2.4	2.5	2.4	1.5	1.2	3.2	0.8	4.7	4.4	3.5	3.8	3.8	3.5	4.1	4.1	3.9	3.2	4.1
OthAgriIrig	0.0	-2.1	-1.9	-4.8	-5.1	-5.0	-4.8	-2.2	-2.5	-1.5	-0.6	13.6	-2.4	-3.2	-3.2	-4.8	-3.1	-3.1	-4.2	-4.3	-0.4
AgriSrvces	0.0	-0.6	-0.8	-2.0	-2.1	-2.1	-1.5	-0.5	-1.3	-0.5	-0.6	-1.2	-0.9	-1.4	-1.4	0.0	-1.7	-1.7	-0.6	-0.4	-1.4
GinnedCotton	0.0	-2.0	-2.0	-2.3	-2.4	-2.2	-2.1	-2.0	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.9
ForestFish	0.0	-0.1	0.0	-0.4	-0.5	-0.4	-0.3	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.1
Mining	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
MeatProds	-0.2	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.1	0.1	0.0	-0.1	-1.0	0.0	-0.1	0.0	-0.2	0.0	0.0	-0.1	-0.1	-0.1
DairyProds	0.0	-0.2	0.0	-1.5	0.0	-1.5	0.0	-0.2	0.0	-0.7	-0.4	-0.3	0.0	-1.1	-1.6	-0.8	-1.9	-1.9	-1.0	-0.8	-1.4
FruitVeg	0.0	0.0	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.3	0.3	0.1	0.1	0.1	0.0	0.1	0.1	-0.1	0.0	0.1
OthFodTobDrk	-0.5	-0.1	-0.1	-0.4	-0.6	-0.6	-0.4	-0.1	-0.2	0.0	0.1	0.0	0.0	-0.2	-0.2	-0.2	-0.7	-0.7	-0.2	-0.2	-0.3
FlourCereals	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	-0.2	0.0	-0.1	-0.5	-0.4	0.0	-0.4	0.0	-0.2	-0.5	-0.5	-0.4	0.0	-0.4
WineSpirits	0.0	0.0	0.0	-0.2	0.0	-0.2	0.0	0.0	0.0	0.0	-0.1	0.1	-0.3	-0.3	0.0	-0.1	-0.2	-0.2	-0.3	-0.3	0.0
TCFs	-0.5	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	0.1	-0.3	-0.4	-1.1	0.1	-0.3	0.0	-0.1	0.0	0.0	-0.4	0.0	-0.2
WoodPaper	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3
PrintPublish	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
OthManufact	-0.3	0.0	-0.1	-0.4	-0.5	-0.4	-0.2	0.0	-0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ElectricGas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WaterDrains	-0.2	0.0	-0.1	-0.2	-0.2	-0.2	-0.3	0.0	-0.3	0.0	0.6	0.1	-0.1	-0.1	0.0	-0.1	-0.2	-0.2	-0.3	-0.1	0.0
OtherSrvces	-0.2	0.0	0.0	-0.3	-0.3	-0.3	-0.1	0.0	0.0	0.1	0.1	0.1	-0.1	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.1

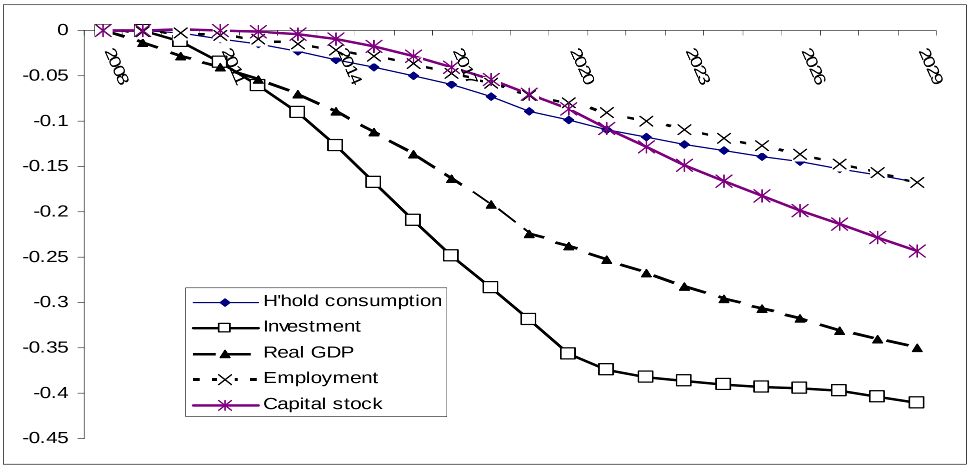
1.3 A variant: all buyback proceeds exit the basin

In the main scenario, we assume that all buyback proceeds stay within the basin. We know that this is not realistic, as some irrigators will use the proceeds to move out of the basin. At the same time, there are many irrigators with strong community ties who will remain within the basin. It is probable, if they are planning to retire, that they will move to a nearby larger regional town with a better array of health, recreational and aged care services. That way, they can maintain community ties while improving access to local services.

We run the model again with all proceeds exiting the basin. From Table 3, basin-wide real household consumption rises by 0.14 percent relative to the baseline in 2029 when all proceeds stay within the basin. Buyback annuities amount to 0.25 percent of aggregate consumption basin-wide (Table 3, row (16)). Without running the model again, we estimate that aggregate consumption in 2029 will fall by 0.11 percent without the annuities (=0.14% – 0.25%). The actual outcome for 2029 is a fall in basin-wide aggregate consumption of 0.17 percent.

What accounts for the small difference between our estimate (-0.11%) and the modelled result (-0.17%)? The simplest explanation is that if the annuities are spent in the basin, they stimulate services and thereby raise basin-wide GDP relative to no annuities. Real GDP falls slightly relative to the main scenario, being 0.35 percent rather than 0.29 percent below the baseline in 2029. Employment which had fallen to 600 jobs below the baseline in 2029 in the main scenario is now around 1000 jobs below the baseline.

Figure 8: Macroeconomic impacts, MDB (all proceeds exit)
% change from the baseline



We do not report the detailed sectoral and regional results for the variant. The main difference between the two sets of results is not in the farming sectors. Rather, differences arise in the services sectors driven by the diminished income effect due to the exit of buyback proceeds from the basin. Services are predominantly local, with relatively limited inter-regional trades.

2. Including infrastructure upgrades and consequent water efficiency gains in the scenario

In this scenario we overlay the main scenario with infrastructure upgrades. These upgrades are outlined in the Australian Government's Water for the Future progam. The program allocates a larger expenditure to infrastructure upgrades than to buybacks. The first point to note is that these upgrades amount to a significant proportion of aggregate investment in the basin, peaking at over $700 million in 2016. The direct impact of spending of this magnitude is apparent in Figure 8, which shows the macroeconomic impacts of buybacks plus infrastructure upgrades. The extent of the employment impact on basin regions will depend on how much the upgrades rely on purchases of materials that originate outside the basin. The higher the purchases of materials from outside the basin as a share of total expenditure, the smaller the employment within the basin. In the absence of a detailed spending breakdown, the default investment expenditure shares in TERM-H2O for the water utilities sector were used to ascribe the direct impacts on the model.

Figure 9: Macroeconomic impacts (buybacks + upgrades), MDB
% change from the baseline

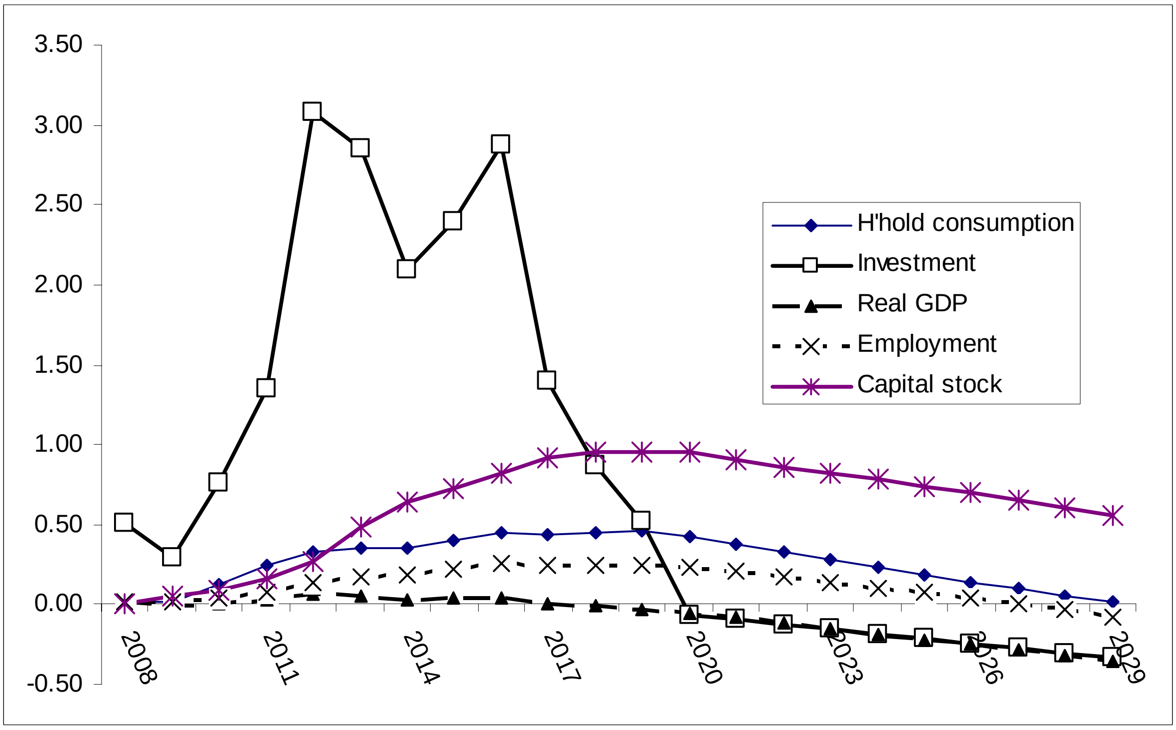


Figure 9 shows that employment rises to as much as 0.25 percent or 1400 jobs above baseline levels as a consequence of the water infrastructure upgrades. Once the upgrades have finished in 2019, employment gradually moves back towards baseline levels. That employment persists above the baseline for a number of years after upgrades have finished reflects realized water savings that arise from the investments. By 2029, employment has returned to base.

Since infrastructure upgrades result in water efficiency gains, water becomes relatively less scarce in this scenario than in the main scenario which does not include such gains. By 2029, the average water price in the scenario is $163/ML (2008 dollars) rather than $194/ML as in the first scenario (Figure 10).

Figure 10: Average basin water price (buybacks + upgrades) v. baseline (2008 dollars)

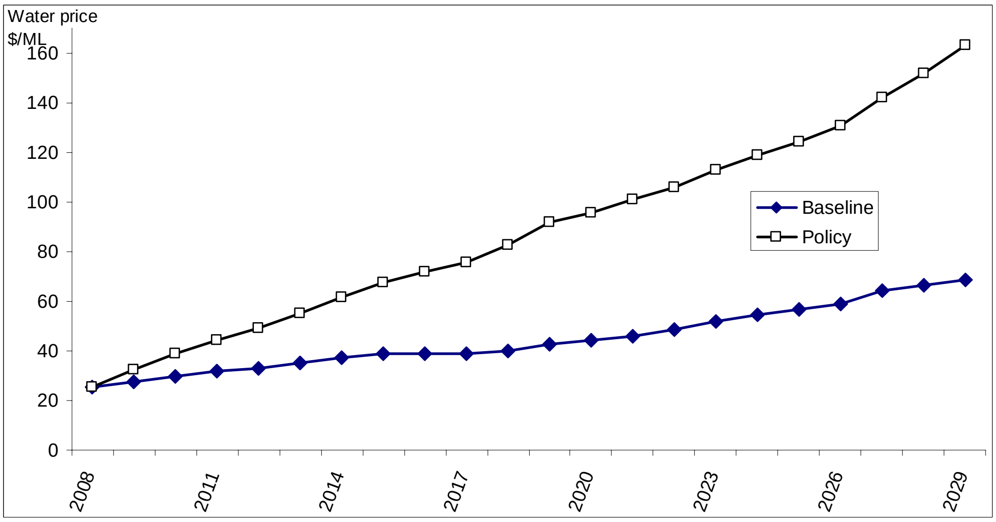
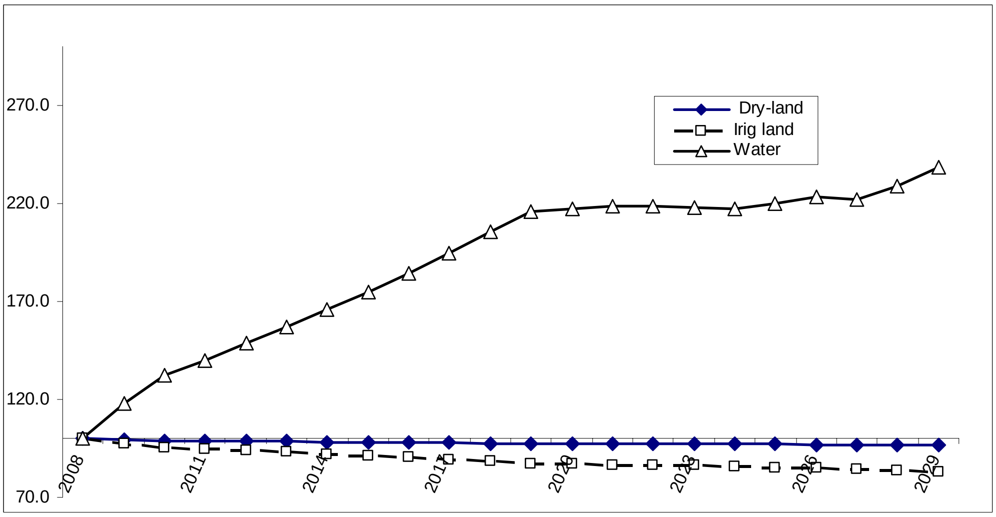


Figure 11 Land rentals and water price (buybacks + upgrades), baseline=100



Since effective water availability is higher than in the first scenario, the drop in land rentals is smaller than in the first scenario (comparing Figures 3 and 11). Overall, the results follow a similar pattern as that of the first scenario, except that the changes are smaller.

At the national level, the decline in real GDP is larger than in the buyback only scenario. By 2029, real GDP is 0.015 percent below the baseline. This indicates that the water savings arising from infrastructure upgrades are relatively more expensive than water purchases.

Figure 12 Basin farm output costs (buybacks + upgrades), % change relative to baseline

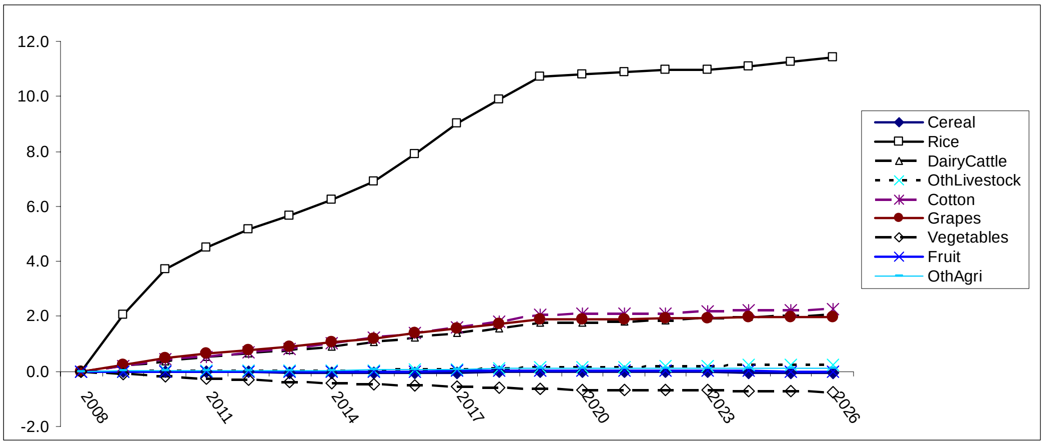


Figure 13 Basin farm outputs (buybacks + upgrades), % change relative to baseline

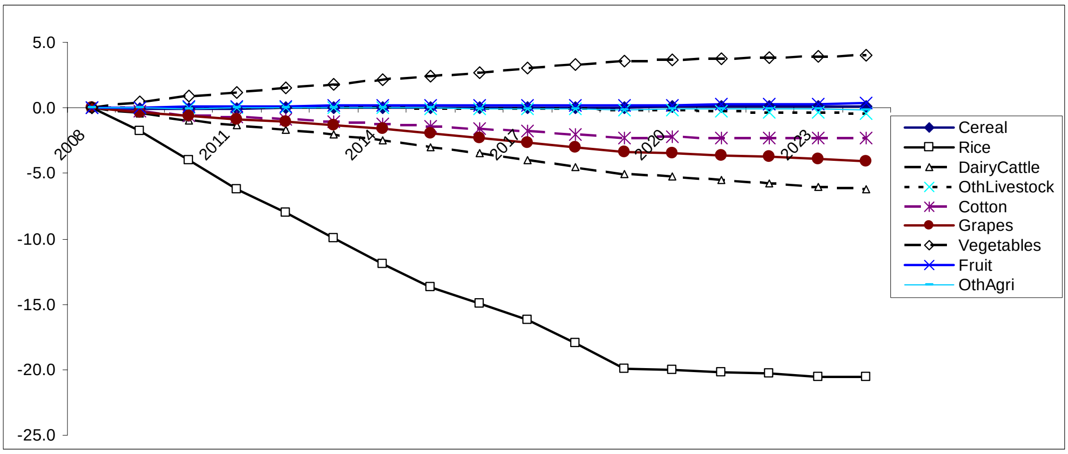


Figure 14 MDB-wide output (buybacks + upgrades), $m change relative to the baseline

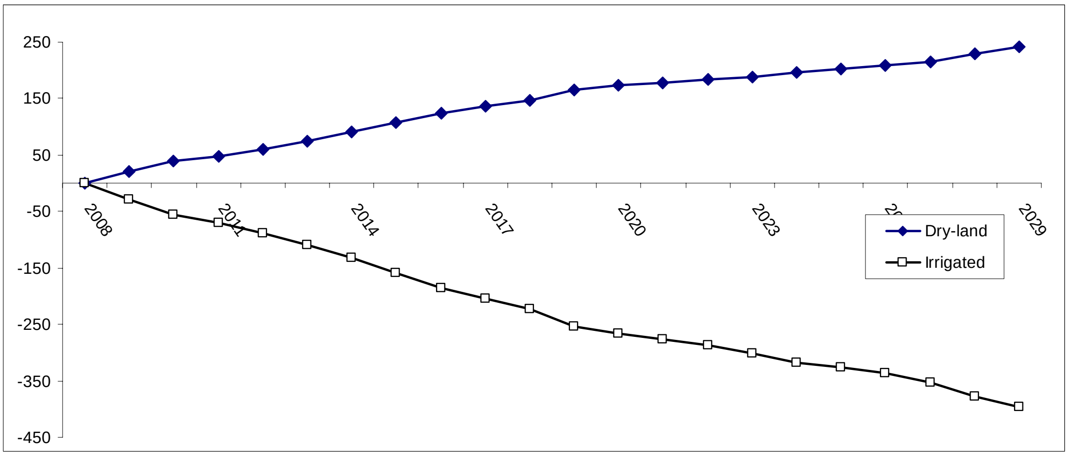


Table 8: Modelled change in basin-wide farm output and water (buybacks + upgrades), 2020 and 2029

(% change relative to baseline)

	Output 2020	Water 2020	Output 2029	Water 2029
Cereal	1.4	-42.0	1.7	-34.7
Rice	-14.6	-33.0	-17.1	-36.5
DairyCattle	-3.7	-34.9	-5.0	-42.0
OthLivestock	0.3	-38.6	0.0	-36.7
Cotton	-2.5	-12.8	-1.1	-12.1
Grapes	-2.3	-22.0	-2.9	-23.3
Vegetables	3.8	-4.9	5.1	-2.6
Fruit	0.5	-12.6	1.0	-11.7
OtherAgriclt	0.7	-12.2	1.1	-11.2

Table 9: NRM sectoral and macro outcomes(buybacks + upgrades), 2020,

(% change relative to baseline)

	DrylandAg	IrigAg	FoodDrinks	Textile	OthManuf	Mining OthPrimary	Utilities	Services	Real GDP	Aggregate consumption	Employment	Employment
	%	%	%	%	%	%	%	%	%	%	%	No.
Paroo	0.5	-5.6	0.0	-0.1	0.1	-0.1	0.0	0.1	0.46	0.31	0.3	3
Namoi	0.9	-1.6	-0.1	-0.8	0.0	-0.1	0.0	0.0	0.31	0.35	0.1	32
Gwydir	1.6	-1.9	0.0	-1.0	-0.2	0.0	0.0	0.1	0.93	1.14	0.2	12
Border	2.1	-3.8	-0.1	-1.1	-0.5	-0.1	0.0	0.0	0.19	0.27	-0.1	-14
Moonie	2.1	-6.2	-0.1	-1.1	-0.7	-0.1	0.0	-0.1	0.02	0.16	-0.2	-2
CondamBalone	1.7	-4.4	-0.1	-1.0	-0.3	-0.1	0.0	0.0	0.17	0.19	-0.1	-22
Warrego	1.0	-2.7	0.0	-1.0	-0.1	-0.1	0.0	0.1	0.44	0.38	0.3	7
MacCastlr	0.4	-0.7	0.0	-0.6	0.0	-0.1	0.0	0.1	0.17	0.13	0.2	114
BarwonDarlng	1.5	-2.5	0.1	-1.1	-0.1	-0.1	0.0	0.2	0.66	0.72	0.2	7
Lachlan	-0.7	2.0	0.0	-0.1	0.0	-0.1	0.0	0.2	0.46	0.33	0.3	69
MrmbidgeeNSW	3.4	-4.1	-0.1	-0.1	0.2	-0.1	0.0	0.2	0.80	0.66	0.5	306
MurrayNSW	8.4	-6.3	-0.1	-0.4	0.1	-0.2	0.0	0.3	1.09	0.89	0.5	235
LowerDarling	2.9	-1.6	-0.2	0.2	0.2	-0.2	0.0	0.3	0.38	0.04	0.9	27
MurrayVic	2.8	-2.5	-0.2	-0.1	0.0	-0.1	0.0	0.1	0.53	0.44	0.3	177
WimmAvoca	2.4	-8.8	0.0	0.2	-0.1	-0.2	0.0	0.2	1.04	0.95	0.7	19
Loddon	2.3	-7.4	-0.1	0.0	0.0	-0.1	0.0	0.0	0.00	-0.02	0.0	-9
GoulbnBroken	3.4	-4.0	-0.3	0.1	0.0	-0.1	0.0	0.1	0.48	0.33	0.3	194
Campaspe	3.9	-5.3	-0.3	0.1	0.0	-0.1	0.0	0.1	0.43	0.26	0.2	35
Ovens	3.6	-6.3	-0.1	-0.1	0.0	0.0	0.0	0.0	0.20	0.15	0.1	11
MurraySA	1.8	-2.0	-0.1	0.2	0.2	-0.1	0.0	0.2	0.63	0.37	0.6	181
All MDB	3.5	-5.0	-0.2	-0.1	0.1	0.1	0.0	0.1	-0.05	0.42	0.23	1380

Table 10: NRM sectoral and macro outcomes(buybacks + upgrades), 2029,
(% change relative to baseline)

	DrylandAg	IrigAg	FoodDrinks	Textile	OthManuf	Mining OthPrimary	Utilities	Services	Real GDP	Aggregate consumption	Employment	Employment
	%	%	%	%	%	%	%	%	%	%	%	No.
Paroo	0.5	-7.1	-0.1	-0.3	-0.1	0.0	-0.9	0.0	0.28	0.20	0.1	1
Namoi	1.2	-1.8	-0.1	-1.2	-0.1	0.0	-0.3	0.0	0.24	0.31	0.0	5
Gwydir	2.3	-2.0	-0.1	-1.4	-0.3	0.0	-0.6	0.0	0.77	1.03	0.0	3
Border	2.2	-4.2	-0.2	-1.8	-1.2	0.0	-0.8	-0.3	-0.17	-0.07	-0.4	-50
Moonie	2.1	-6.2	-0.4	-1.9	-1.7	0.1	-0.5	-0.3	-0.34	-0.18	-0.5	-5
CondamBalone	1.7	-4.7	-0.2	-1.6	-0.8	0.0	-0.4	-0.3	-0.15	-0.11	-0.4	-154
Warrego	1.0	-2.9	-0.1	-1.4	-0.2	0.0	-0.7	0.0	0.26	0.21	0.0	1
MacCastlr	0.4	-0.8	0.0	-1.0	0.0	0.0	-0.2	0.0	0.13	0.10	0.1	77
BarwonDarlng	1.9	-2.5	0.1	-1.4	-0.1	0.0	-0.3	0.1	0.57	0.62	0.1	5
Lachlan	-0.6	2.0	0.1	-0.2	0.0	0.0	-1.9	0.1	0.3	0.23	0.2	50
MrmbidgeeNSW	3.5	-3.5	0.0	-0.2	0.1	0.1	-1.4	0.2	0.6	0.54	0.4	244
MurrayNSW	5.9	-4.2	-0.1	-0.7	0.1	0.0	-1.8	0.2	0.59	0.36	0.4	160
LowerDarling	2.9	-1.6	0.0	0.2	-0.1	0.1	-2.8	0.1	0.04	-0.17	0.5	15
MurrayVic	3.1	-2.9	-0.1	-0.2	-0.1	0.0	-2.0	0.1	0.24	0.17	0.1	72
WimmAvoca	2.6	-8.8	-0.1	0.1	-0.4	0.0	-3.0	0.1	0.63	0.63	0.4	12
Loddon	2.1	-7.9	-0.2	-0.1	0.0	0.0	-0.1	0.0	-0.06	-0.11	0.0	-27
GoulbnBroken	3.4	-4.5	-0.5	0.0	-0.1	0.0	-1.4	0.0	0.19	0.05	0.1	53
Campaspe	3.9	-6.3	-0.5	0.0	-0.1	0.1	-1.5	0.0	0.12	-0.06	0.0	1
Ovens	3.6	-7.2	-0.2	-0.3	0.0	0.0	-0.2	0.0	0.04	-0.02	0.0	-3
MurraySA	1.9	-2.5	-0.1	0.1	0.0	0.0	-1.8	0.1	0.25	0.06	0.3	89
All MDB	3.3	-5.2	-0.2	-0.1	0.0	0.0	0.0	0.1	-0.16	0.20	0.1	550

From the perspective of farm output, the gains we estimate from a simple database calculation are much larger than modelled gains. A database calculation indicates that in 2020, fully implemented SDLs plus infrastructure upgrades reduce basin farm output by 6.8 percent (Table 11) instead of 9.3 percent (Table 3), a boost of 2.5 percent in basin farm output. But the modelled outcome is for a reduction in farm output of 0.7 percent compared with 1.1 percent without the upgrades, a boost of only 0.4 percent. The apparent gain from infrastructure upgrades is much smaller once we include in the model farmer responses to water scarcity such as movements to dry-land production. This implies that we will overestimate the marginal impact of infrastructure upgrades and additional available water if we assume that irrigation output is proportional to water availability.

During years of drought, the story differs. The marginal benefits of infrastructure upgrades will increase for two reasons. First, the price of water rises substantially during drought so that additional water becomes increasingly valuable (see appendix 3). Second, if water from infrastructure upgrades is of very high security, then its availability will fall by a smaller proportion than irrigation water overall during drought. In part, therefore, some infrastructure upgrades may be justifiable as a form of drought insurance.

Table 11: Comparing database calculations to modelled impacts in 2020 and 2029 (buybacks + upgrades) -- (% change relative to base)

Year 2020	Basin-wide MDB	TmwthNSlpNSW	NCentralNSW	MacquarieNSW	McqrieBarNSW	UpDarlingNSW	CntralWstNSW	LachlanNSW	WagCntMrmNSW	LMrmbNSW	MurrayNSW	MrryDrlngNSW	MalleeVic	LoddonVic	GoulburnVic	OvnsMurryVic	DrlngDwnsQld	SouthWQld	MurrayLndsSA
Model																			
(1) Farm income (%)	-0.61	-0.2	-0.5	-0.1	-0.1	-0.6	-0.2	0.2	-0.6	-0.7	-2.2	-0.5	-0.5	-0.8	-0.8	-1.0	-0.8	-0.3	-0.4
(2) Real GDP (%)	-0.05	0.0	-0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.2	0.0	-0.1	0.0	-0.1	-0.1	-0.1	-0.4	-0.1	0.0
(3) Employment (%)	0.23	0.1	0.1	0.2	0.3	0.2	0.1	0.3	0.2	1.1	0.5	0.8	0.6	0.0	0.3	0.0	-0.2	0.2	0.6
(4) Household consumption (%)	0.42	0.1	1.2	0.2	0.9	0.7	0.1	0.5	0.2	2.2	1.1	0.4	1.0	0.0	0.5	0.2	0.1	0.3	0.6
(5) Annuity: % of consumption	0.38	0.1	0.7	0.1	0.6	0.5	0.1	0.3	0.2	1.5	1.1	0.4	0.9	0.1	0.5	0.2	0.3	0.3	0.6
(6)Terms of trade[a]	0.21	0.1	1.5	0.1	0.5	0.5	0.0	0.1	0.1	0.9	0.2	0.3	0.4	0.0	0.2	0.1	0.4	0.5	0.2
(7) Net water trade (GL)	0	0	0	0	0	0	0	0	66.3	9.5	24.0	-15.1	1.8	3.4	-81.4	1.3	0.0	0.0	-9.7
Database calc.																			
(8) Farm income (%)	*-6.8*	*-1.6*	*-4.1*	*-1.7*	*-2.1*	*-4.3*	*-2.3*	*0.3*	*-3.1*	*-9.0*	*-13.7*	*-22.1*	*-8.7*	*-8.1*	*-13.1*	*-8.3*	*-6.2*	*-2.3*	*-9.4*
(9) Real GDP (%)	*-0.7*	*-0.1*	*-0.8*	*-0.1*	*-0.2*	*-0.3*	*0.0*	*0.0*	*-0.1*	*-1.8*	*-1.3*	*-3.8*	*-1.2*	*-0.1*	*-1.1*	*-0.3*	*-0.8*	*-0.2*	*-1.8*
(10) Employment (%)	*-0.7*	*-0.1*	*-0.8*	*-0.1*	*-0.2*	*-0.3*	*0.0*	*0.0*	*-0.1*	*-1.8*	*-1.3*	*-3.8*	*-1.2*	*-0.1*	*-1.1*	*-0.3*	*-0.8*	*-0.2*	*-1.8*
(11) Household consumption (%)	*-0.7*	*-0.1*	*-0.8*	*-0.1*	*-0.2*	*-0.3*	*0.0*	*0.0*	*-0.1*	*-1.8*	*-1.3*	*-3.8*	*-1.2*	*-0.1*	*-1.1*	*-0.3*	*-0.8*	*-0.2*	*-1.8*
Year 2029																			
Model																			
(12) Farm income (%)	-0.72	-0.2	-0.4	-0.1	-0.2	-0.7	-0.1	0.2	-0.6	-0.1	-1.9	-0.4	-0.5	-1.0	-1.1	-1.4	-1.3	-0.5	-0.5
(13) Real GDP (%)	-0.16	0.0	-0.2	0.0	0.0	0.0	0.0	0.1	-0.1	0.3	-0.1	-0.2	-0.1	-0.1	-0.3	-0.1	-0.6	-0.2	-0.2
(14) Employment (%)	0.08	0.0	-0.1	0.1	0.2	0.2	0.1	0.2	0.1	1.0	0.3	0.5	0.3	0.0	0.1	0.0	-0.5	0.0	0.3
(15) Household consumption (%)	0.20	0.1	0.9	0.2	0.7	0.6	0.0	0.3	0.1	1.8	0.6	0.0	0.5	-0.1	0.2	0.0	-0.3	0.2	0.3
(16) Annuity: % of consumption	0.25	0.1	0.4	0.1	0.4	0.3	0.0	0.2	0.1	1.0	0.7	0.3	0.6	0.0	0.3	0.1	0.1	0.1	0.4
(17) Terms of trade[a]	0.29	0.1	2.3	0.1	0.8	0.6	0.0	0.0	0.1	1.1	0.2	0.4	0.4	0.0	0.3	0.1	0.5	0.7	0.3
(18) Net water trade (GL)	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.6	0.8	-32.6	-14.8	12.3	9.1	-60.0	6.0	0.0	0.0	-3.3
Database calc.																			
(19) Farm income (%)	*-6.8*	*-1.9*	*-4.8*	*-1.9*	*-2.6*	*-5.0*	*-2.3*	*0.3*	*-3.1*	*-8.9*	*-13.7*	*-21.8*	*-8.4*	*-7.9*	*-12.8*	*-8.3*	*-6.9*	*-2.8*	*-9.2*
(20) Real GDP (%)	*-0.7*	*-0.1*	*-1.3*	*-0.1*	*-0.4*	*-0.6*	*-0.1*	*0.0*	*-0.1*	*-1.9*	*-1.4*	*-3.9*	*-1.2*	*-0.2*	*-1.1*	*-0.3*	*-1.1*	*-0.3*	*-1.8*
(21) Employment (%)	*-0.7*	*-0.1*	*-1.3*	*-0.1*	*-0.4*	*-0.6*	*-0.1*	*0.0*	*-0.1*	*-1.9*	*-1.4*	*-3.9*	*-1.2*	*-0.2*	*-1.1*	*-0.3*	*-1.1*	*-0.3*	*-1.8*
(22) Household consumption (%)	*-0.7*	*-0.1*	*-1.3*	*-0.1*	*-0.4*	*-0.6*	*-0.1*	*0.0*	*-0.1*	*-1.9*	*-1.4*	*-3.9*	*-1.2*	*-0.2*	*-1.1*	*-0.3*	*-1.1*	*-0.3*	*-1.8*

a Weighted using aggregate consumption(C), using the formula $(p_x-p_m)*X/C$ where p_x and p_m are the percentage changes in import and export price indexes, and X aggregate exports (international + inter-regional).

Table 12: NRM sectoral impact (buybacks + upgrades), 2020 (% change relative to baseline)

t	Paroo	Namoi	Gwydir	Border	Moonie	CondamBalone	Warrego	MacCastlr	BarwonDarlng	Lachlan	MrmbidgeeNSW	MurrayNSW	LowerDarling	MurrayVic	WimmAvoca	Loddon	GoulbnBroken	Campaspe	Ovens	MurraySA
CerealDryL	0.4	0.6	1.1	1.8	1.9	1.5	0.7	0.2	0.7	-0.8	3.8	9.6	2.9	2.7	2.6	2.5	3.2	3.2	3.5	1.8
CerealIrig	-12.7	-10.3	-15.7	-24.4	-25.7	-22.5	-14.4	-6.8	-14.1	4.2	-18.6	-9.8	-21.0	-18.5	-18.4	-24.0	-20.4	-20.4	-24.1	-18.4
Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-16.4	-8.9	0.0	-23.6	0.0	0.0	-18.9	-18.9	0.0	0.0
DairyCatDryL	0.0	3.6	0.0	0.0	0.0	6.6	0.0	3.1	0.0	0.2	9.2	10.8	0.0	8.7	0.0	8.0	8.8	8.8	9.1	7.0
DairyCatIrig	0.0	-2.4	0.0	0.0	0.0	-7.0	0.0	-1.4	0.0	3.0	-9.2	0.7	0.0	-7.3	-5.6	-8.3	-5.9	-5.9	-8.0	-6.0
OthLivstoDry	0.6	0.6	0.8	1.7	1.8	1.4	0.6	0.4	1.3	-0.4	2.7	8.3	2.5	2.8	2.0	2.0	2.8	2.8	3.1	1.6
OthLivstoIrg	-5.6	-4.7	-5.7	-11.5	-12.1	-10.0	-5.7	-3.1	-7.8	1.6	-8.5	-17.1	-9.0	-11.0	-8.4	-13.1	-9.9	-9.9	-11.9	-9.4
CottonDryL	0.0	5.7	6.1	6.8	7.1	5.7	6.1	4.0	6.1	2.8	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CottonIrig	-0.4	-0.9	-1.4	-3.7	-4.5	-2.5	-2.0	1.3	-2.0	5.2	-3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grapes	-1.0	-0.4	0.0	-3.8	0.0	-1.6	-2.2	-0.1	-2.2	0.0	1.3	5.7	-2.7	-2.7	0.0	-5.2	-5.5	-5.5	-4.8	-2.6
Vegetables	0.0	0.8	-0.2	0.9	0.0	0.9	0.0	0.0	0.0	-1.2	9.4	18.2	4.0	2.9	0.0	1.8	3.8	3.8	3.3	2.2
FruitDryL	0.0	0.7	1.6	2.5	0.0	2.0	0.0	0.6	0.0	-0.7	4.7	5.5	3.2	3.0	0.0	2.8	3.4	3.4	3.6	2.2
FruitIrig	-0.9	-0.7	-0.6	-1.5	0.0	-1.3	-0.4	-0.5	-0.4	-0.2	2.3	6.3	-0.1	-0.3	-0.3	-1.4	-0.1	-0.1	-0.8	-0.8
OthAgriDry	0.0	0.7	0.8	2.4	2.5	2.3	0.9	0.5	1.4	-0.7	3.2	3.6	2.7	2.5	2.5	2.9	3.1	3.1	3.5	2.0
OthAgriIrig	0.0	-1.4	-1.5	-3.4	-3.6	-3.4	-1.9	-1.0	-2.2	0.1	-0.5	7.9	-1.9	-2.1	-2.1	-3.7	-2.1	-2.1	-3.3	-2.6
AgriSrvces	0.0	-0.3	-0.4	-0.9	-0.9	-0.9	-0.8	-0.1	-0.6	-0.2	-0.3	-0.3	-0.5	-0.6	-0.6	0.0	-0.6	-0.6	0.0	0.0
GinnedCotton	0.0	-1.0	-1.0	-1.1	-1.1	-1.0	-1.1	-0.9	-1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ForestFish	0.0	0.0	0.0	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1
Mining	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1
MeatProds	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.3	0.0	0.1	0.1	-0.1	0.1	0.1	0.0	0.0
DairyProds	0.0	-0.1	0.0	-0.6	0.0	-0.6	0.0	-0.1	0.0	-0.1	-0.2	-0.1	0.0	-0.5	-0.6	-0.4	-0.8	-0.8	-0.5	-0.4
FruitVeg	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OthFodTobDrk	0.0	0.0	0.0	-0.1	-0.2	-0.2	0.0	0.0	0.0	0.1	0.1	0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.1	0.0
FlourCereals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.3	-0.3	0.0	-0.2	0.0	-0.1	-0.2	-0.2	-0.2	0.1
WineSpirits	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.3	0.0	-0.3	-0.3	0.0	-0.1	-0.1	-0.1	-0.1	-0.2
TCFs	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.4	0.2	-0.1	0.2	0.0	0.1	0.1	-0.1	0.2
WoodPaper	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	-0.2	-0.2	-0.1	0.0	0.0	-0.1	-0.1	-0.1	-0.1
PrintPublish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1
OthManufact	0.1	0.0	-0.1	-0.2	-0.2	-0.2	0.1	0.1	0.0	0.1	0.3	0.2	0.6	0.1	0.3	0.0	0.1	0.1	0.0	0.2
ElectricGas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WaterDrains	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OtherSrvces	0.1	0.0	0.1	0.0	-0.1	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.1	0.2	0.0	0.1	0.1	0.0	0.2

Table 13: NRM sectoral impact (buybacks + upgrades), 2029 (% change relative to baseline)

	Paroo	Namoi	Gwydir	Border	Moonie	CondamBalone	Warrego	MacCastlr	BarwonDarlng	Lachlan	MrmbidgeeNSW	MurrayNSW	LowerDarling	MurrayVic	WimmAvoca	Loddon	GoulbnBroken	Campaspe	Ovens	MurraySA
CerealDryL	0.4	0.9	2.1	2.1	2.0	1.7	0.9	0.2	1.3	-0.8	3.9	7.3	3.0	3.0	3.0	2.5	3.2	3.2	3.3	2.0
CerealIrig	-20.0	-12.1	-17.9	-32.9	-34.9	-31.8	-23.0	-7.9	-21.9	4.1	-18.4	-6.3	-20.4	-18.4	-18.3	-23.4	-20.3	-20.3	-23.6	-19.3
Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-19.7	-8.1	0.0	-27.6	0.0	0.0	-23.0	-23.0	0.0	0.0
DairyCatDryL	0.0	4.6	0.0	0.0	0.0	7.6	0.0	3.6	0.0	0.6	10.8	8.5	0.0	9.8	0.0	9.0	10.1	10.1	10.2	9.0
DairyCatIrig	0.0	-3.8	0.0	0.0	0.0	-11.6	0.0	-1.5	0.0	5.0	-12.3	3.6	0.0	-9.6	-7.2	-10.7	-7.7	-7.7	-10.6	-8.5
OthLivstoDry	0.6	0.7	1.0	1.7	1.7	1.3	0.6	0.4	1.6	-0.3	2.5	5.6	2.3	2.8	1.9	1.8	2.7	2.7	3.1	1.7
OthLivstoIrg	-7.7	-5.6	-7.0	-14.3	-15.1	-12.9	-7.8	-3.1	-10.3	1.7	-7.6	-16.4	-8.1	-10.9	-7.9	-12.7	-9.7	-9.7	-11.9	-10.0
CottonDryL	0.0	4.6	5.0	5.0	4.9	3.9	5.1	3.0	5.1	2.4	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CottonIrig	-1.0	-1.2	-1.8	-4.0	-4.7	-2.9	-2.3	0.8	-2.2	4.0	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grapes	-2.3	-0.8	0.0	-6.9	0.0	-3.3	-2.8	0.0	-2.8	0.0	2.5	10.5	-3.2	-3.4	0.0	-6.9	-7.6	-7.6	-6.5	-3.7
Vegetables	0.0	6.6	-0.2	1.2	0.0	1.2	0.0	0.2	0.0	-1.5	11.7	23.5	5.4	4.0	0.0	3.0	5.3	5.3	4.6	3.2
FruitDryL	0.0	0.8	1.7	3.1	0.0	2.4	0.0	0.5	0.0	-0.9	5.1	4.7	3.5	3.7	0.0	3.2	3.8	3.8	3.9	2.6
FruitIrig	-1.6	-0.8	1.3	-2.5	0.0	-2.3	0.8	-0.5	0.8	-0.4	4.0	11.0	0.6	0.0	0.0	-1.5	0.4	0.4	-0.6	-0.9
OthAgriDry	0.0	0.5	0.7	2.1	2.2	2.0	0.6	0.2	1.5	-0.8	2.7	1.7	2.1	2.3	2.3	2.4	2.5	2.5	2.7	1.8
OthAgriIrig	0.0	-1.6	-1.3	-4.3	-4.6	-4.4	-2.7	-1.1	-0.9	-0.3	0.1	11.2	-1.5	-1.9	-1.9	-3.2	-1.6	-1.6	-2.8	-2.7
AgriSrvces	0.0	-0.4	-0.7	-2.0	-2.1	-2.1	-0.8	0.0	-0.4	-0.2	-0.2	-0.4	-0.6	-0.8	-0.8	0.1	-1.0	-1.0	-0.2	-0.2
GinnedCotton	0.0	-1.4	-1.4	-1.8	-1.9	-1.6	-1.4	-1.2	-1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ForestFish	0.0	0.0	0.0	-0.5	-0.5	-0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mining	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1
MeatProds	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.1	0.0	-0.1	-0.5	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.1
DairyProds	0.0	-0.2	0.0	-1.4	0.0	-1.4	0.0	0.0	0.0	0.1	-0.2	0.0	0.0	-0.8	-0.9	-0.6	-1.2	-1.2	-0.7	-0.5
FruitVeg	0.0	0.0	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.1	0.1	0.0	0.1	0.1	0.0	0.0
OthFodTobDrk	-0.2	-0.1	-0.1	-0.4	-0.6	-0.5	-0.2	0.0	0.0	0.1	0.2	0.1	0.1	-0.1	0.0	-0.1	-0.4	-0.4	-0.1	0.0
FlourCereals	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	0.1	-0.3	-0.2	0.0	-0.3	0.0	-0.2	-0.3	-0.3	-0.3	0.0
WineSpirits	0.0	0.0	0.0	-0.2	0.0	-0.2	0.0	0.0	0.0	0.1	0.0	0.2	-0.1	-0.2	0.0	-0.1	-0.1	-0.1	-0.2	-0.2
TCFs	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	0.1	-0.2	-0.2	-0.7	0.2	-0.2	0.1	-0.1	0.0	0.0	-0.3	0.1
WoodPaper	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PrintPublish	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.0	0.1	0.1	0.0	0.1
OthManufact	-0.1	0.0	-0.1	-0.4	-0.5	-0.4	-0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ElectricGas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
WaterDrains	-10.4	-2.8	-2.8	-4.2	-4.8	-6.2	-8.0	-4.1	-6.7	-7.2	-5.4	-5.9	-6.9	-3.0	-3.5	-0.2	-1.9	-1.9	-0.9	-2.9
OtherSrvces	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0	0.0	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1

3. Discussion

If there were no farm factor mobility on basin farms, output losses due to reduced water availability would be a major policy concern. A crude database calculation indicates farm output losses of 9.3 percent relative to base in 2020 due to fully implemented SDLs. But there is substantial evidence of farm factor mobility in the basin in the water accounts prepared by ABS. Water used in cropping of annuals falls by a larger proportion than water allocations when water scarcity worsens. At the same time, dairy production switches substantially to dry-land production. Perennial croppers purchase water in order to compensate for shortfalls in allocations. TERM-H2O allows each of these resource movements to occur in response to changing water availability. As a consequence, fully implemented SDLs amounting to 2800 GL of entitlements being removed from irrigation production lead to a modelled loss in farm output relative to base of 0.9 percent in 2020 and 1.1 percent in 2029. By 2029, economy-wide income in the basin falls by only 0.29 percent, with jobs falling 600 below the baseline.

Household spending in the basin increases relative to the baseline, by 0.34 percent in 2020 and 0.14 percent in 2029. In each case, the increase arises in part from the terms-of-trade improvements in the basin. That is, the price of inter-regional and international exports from the basin rises relative to the price of corresponding imports into the basin. In TERM-H2O, buyback proceeds are treated as an annuity that adds to regional consumption – a second source of gains. Were we to assume that all annuities leave the basin rather than remain, instead of there being a small gain in basin-wide household spending, there would be a small loss. Terms-of-trade impacts that diminish household spending losses would still apply.

The Water for the Future program allocates more funds to infrastructure upgrades than to buybacks of water from farmers. Such upgrades are superficially appealing as a means of dealing with decades old infrastructure. They may increase the availability of water for either farming or environmental uses. This does not mean that such upgrades can be justified at any cost. Consider first the environmental benefits. Buybacks sales by July 2011 amounted to nearly 1100 GL, with an average annual expected allocation of 790 GL. These cost almost $1.7 billion. Using past asset values as a guide, fully implemented buybacks of 2800 GL may cost in excess of $4.0 billion. This contrasts with infrastructure upgrades, which are expected to cost $4.6 billion across the basin and result in additional water available to farmers of around 240 GL, with around 570 GL available to the environment. In terms of value for money, purchasing water from farmers appears to be superior, even after allowing for the higher security of additional water arising from infrastructure upgrades.

From the perspective of farm output, the benefits of additional water are much smaller once we consider farm factor mobility as part of the adjustment process to changes in water availability. The additional available irrigation water due to infrastructure upgrades may increase basin-wide farm output by only 0.4 percent. But during drought years, the marginal benefits of infrastructure upgrades will be much higher, both because additional water is more valuable, and because there is an expectation that this water will have a very high security. In calculating the socially optimal level of public expenditure on infrastructure upgrades, the marginal benefits of these upgrades need to be estimated by considering both normal years and drought years. If the frequency and severity of future droughts increases, the marginal benefits of such upgrades increase. Nevertheless, such benefits may not be sufficient to justify the funds allocated to infrastructure upgrades in the Water for the Future program.

Appendices

A1: Unique features of TERM-H2O

TERM-H2O differs from TERM in that it includes water accounts and theoretical modifications in agriculture. It differs from TERM-Water (Wittwer 2003) in that irrigated sectors include a fixed water requirement per hectare. This requirement varies between activities. In turn, if water becomes scarcer, irrigable land and other inputs may move to dry-land production.

In addition, TERM-H2O includes supply-side modifications: farm factors including owner-operator inputs, mobile capital, irrigable land and dry land follow a CET functional form. That is, factors are allocated between different activities to maximize profits. If, for example, the price of cereals rises relative to other annuals, irrigators may move factors (land, owner-operators, labour, mobile capital and water) so as to increase cereals production and reduce production of other annuals.

Table A1.1: Water consumption, Murray-Darling Basin, 2001-02 to 2005-06

	2001–02	**2002–03**	**2005–06**	**2007–08**
Water consumption (GL)				
Livestock pasture, hay, etc.	2,971	2,343	2,571	997
Rice	1,978	615	1,252	27
Cereals (excl. rice)	1,015	1,230	782	805
Cotton	2,581	1,428	1,574	283
Grapes & fruit	868	916	928	790
Vegetables	152	143	152	124
Other agriculture	504	475	460	116
Total Agriculture	**10,069**	**7,150**	**7,720**	**3,142**
Index (2001-02 = 100)				
Livestock pasture	100	79	87	34
Rice	100	31	63	1
Cereals (excl. rice)	100	121	77	79
Cotton	100	55	61	11
Grapes & fruit	100	106	107	91
Vegetables	100	94	100	82
Other agriculture	100	94	91	23
Total Agriculture	100	71	77	31

Source: ABS (2008), Table 3.20.

Figure A1.1 outlines the theoretical structure of production in farm sectors in TERM-H2O. It does not show the CET form, although this is implied by the fixed water requirement for a given crop per unit of irrigable land. The CET possibilities are an important modification that help the model track observed changes in usage between activities in response to changes in water scarcity. We see these in Table A1.1 for the Murray-Darling basin. Livestock pasture, rice, cereals and cotton exhibited much wider year-to-year variability in water use than grapes and fruit, vegetables or other agriculture.

Dixon *et al*. (2011) details the theoretical modifications unique to TERM-H2O. Here, we outline some of the modifications in reference to Figure A1.1.

Outline of theoretical modifications in TERM-H2O

TERM-H2O includes theoretical detail to distinguish between the responsiveness of sectors that are flexible in the short term, such as irrigated annuals, and sectors that are not flexible, notably irrigated perennials.

The flexibility of irrigated annuals in TERM-H2O

In the bottom right-hand side corner of Figure A1, we see that irrigable land and water form a bundle for each irrigation activity. For a given water-using irrigation technology, there is a fixed water requirement per hectare for each activity. This means that as water availability falls, irrigable land either (1) moves in part to an activity requiring less water per hectare, or (2) the number of hectares of irrigated activity falls, and the number of hectares of dry-land activity increases. In the case of (1), rice producers may move to other cereal production as water scarcity worsens. The most obvious observed case of (2) does not concern annuals, but rather livestock. Dairy herds may move to dry-land production with hand-feeding as water availability falls.

The relative rigidity of adjustment of perennials in TERM-H2O

The theory of TERM-H2O includes imperfect mobility of land, labour, capital and owner-operator inputs to various farm sectors. Such mobility does not make sense when we consider orchards or vineyards, which encapsulate a substantial proportion of farm capital of fruit or grape production. To impose some rigidity on the adjustment of perennial sectors, we include some specific capital for each perennial sector in the database. This is shown in the middle of Table A1, in which specific capital, the land bundle and owner-operator inputs follow CES substitution possibilities for each farm sector. Only perennials and livestock include specific capital so that for the remaining farm sectors, this effectively is a CES bundle of land and owner-operator inputs only.

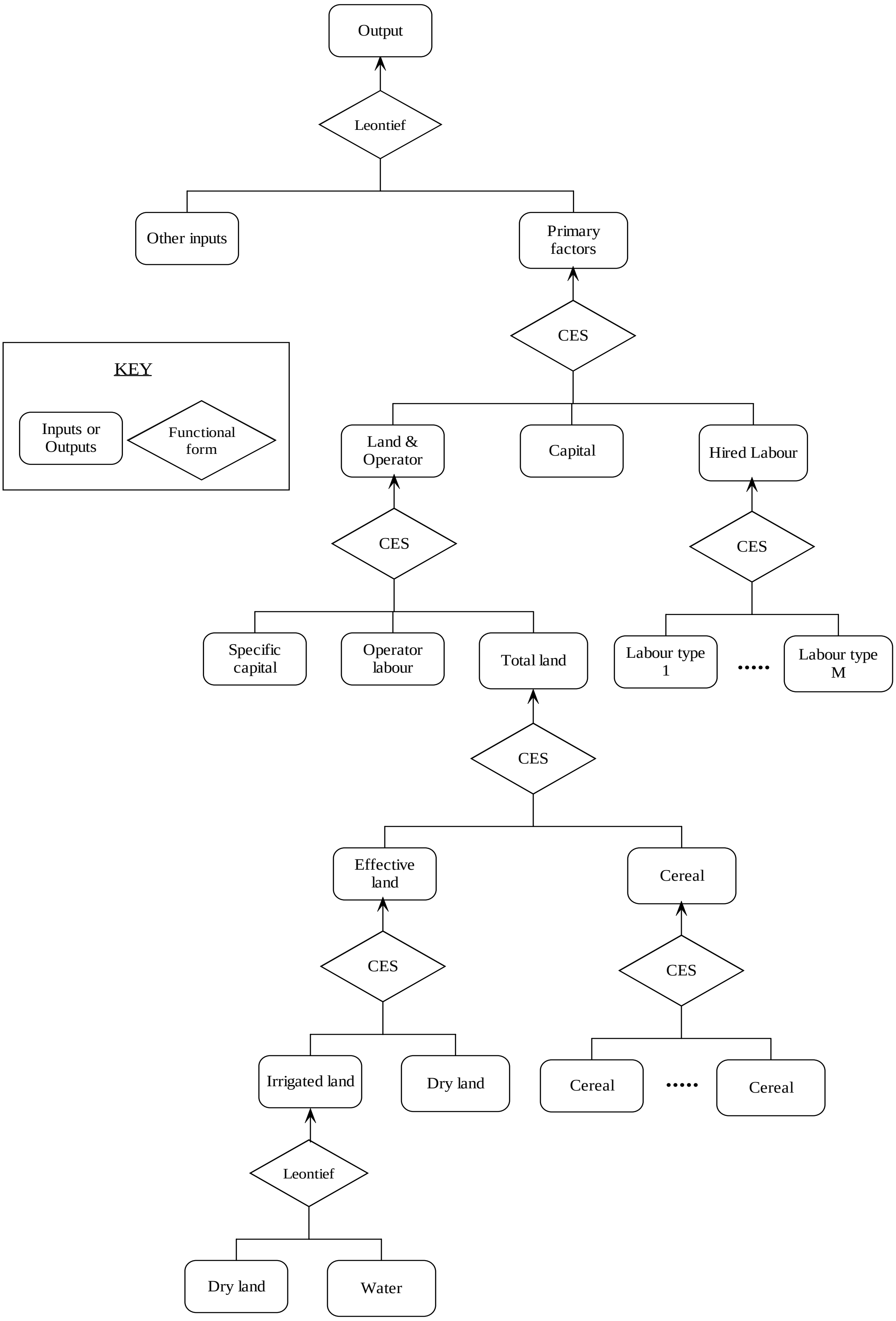
The specific case of livestock herds

Livestock herds (dairy and other livestock in TERM-H2O) are a form of specific capital. The only form of reallocation that is possible for a herd is between dry-land and irrigated technologies. The theory of TERM-H2O allows specific (herd) capital to move between dry-land and irrigated technologies. Without this movement, the reported outcome for the main scenario reported in Table 1, whereby dairy cattle production falls by only 7.3 percent relative to the baseline in 2029 as dairy production water usage falls by 40.8 percent, would not be possible. This entails a substantial movement from irrigation to dry-land production in response to environmental water purchases by the Commonwealth. The specific capital that moves between dry-land and irrigable states also applies to fruit in TERM-H2O.

Water use per unit output as water availability changes

Since the land-water composite at the bottom of Figure A1 enters the land & operator nest near the top of the figure, as the price of water rises relative to other factors, there will be substitution away from water and towards capital and labour. That is, less water is used per unit output as its price rises even though in each irrigation activity, there is a constant requirement of water per hectare of irrigable land.

Figure A1.1: Production function for farm sectors



A2. Further explanation of modelled outcomes

Correlation between dry land and irrigable land rentals

Following Dixon *et al*. (2011) which contains very detailed explanations of modelled buyback impacts, the modelled percentage change in the price of irrigable land (pirrl(d,t)) in each region and year in the present simulation is closely related to the percentage change in the price of water (pwater(d,t)):

$$\text{pirrl}(d,t) = -1.66 -1.20 \times (\text{VWTOT}(d,t)/[\text{VWTOT}(d,t)+ \text{VIRTOT}(d,t)]) \times \text{SHIR}(d,t) \times \text{pwater}(\text{d},t) \qquad R^2=0.98 \qquad \text{(A1)}$$

The subscript d refers to the basin region, and t to the year.
VWTOT=baseline water costs
VIRTOT=baseline irrigable land rentals
SHIR = baseline irrigation share of farm sector's primary factor income

We can observe the negative correlation between water prices and irrigable land prices by comparing Figures 2 and 3.

The explanation in Dixon et al. of sectoral farm output changes by region and year

Dixon et al. (2011) devise a series of equations that explain sectoral outcomes by region and year in terms of the weighted changes in the price of water, irrigable land and dry land. The equation is:

$$\begin{aligned}\text{xtot}(i,d,t) = \text{a}_0 &+ \text{a}_1 \times \text{C}_{\text{avg}}(i,t)\\ &+ \text{a}_2 \times [\text{C}_{\text{com}}(i,d,t) - \text{C}_{\text{avg}}(i,t)\\ &+ \text{a}_3 \times [\text{C}(i,d,t) - \text{C}_{\text{com}}(i,d,t)]\end{aligned} \qquad \text{(A2)}$$

i refers to each farm sector.
xtot(i,d,t) = % change in industry output relative to the baseline
$\text{C}_{\text{avg}}(i,t)$ = basin-wide average of commodity (dryland + irrigated) production costs
$\text{C}_{\text{com}}(i,d,t)$ = commodity composite (dryland + irrigated) fall in production costs
C(i,d,t) = industry costs (explained by weighted changes in the price of water, irrigable land and dry land).

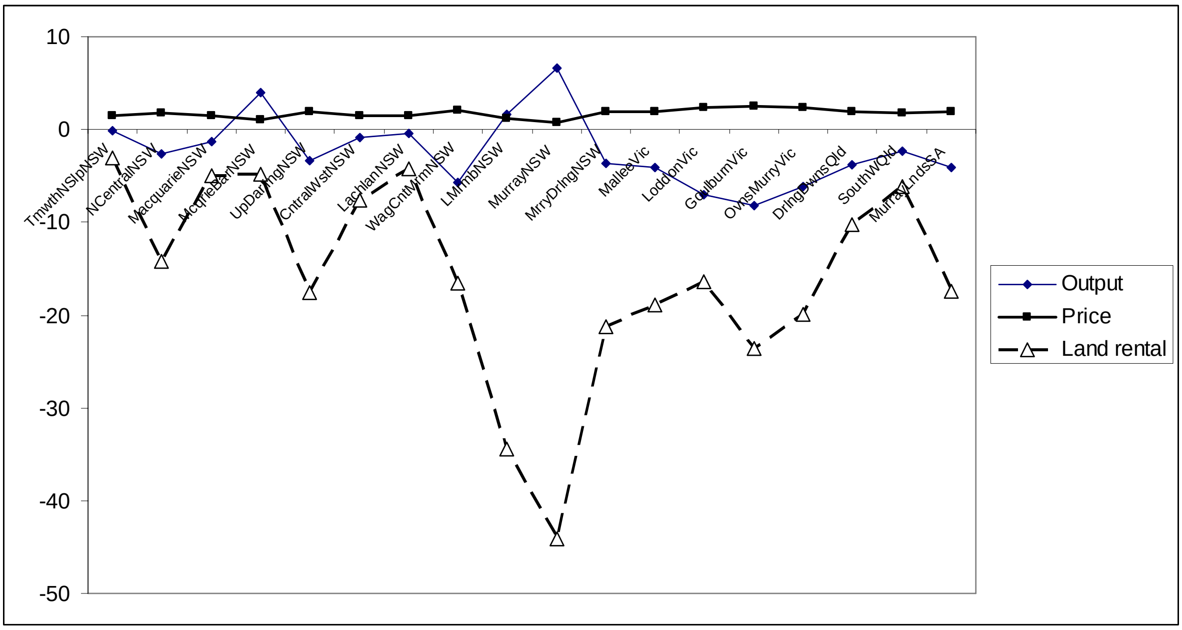
- Figure 5 gives us an indication of $\text{C}_{\text{avg}}(i,t)$ for each farm commodity produced in the basin. Figure 6 gives the basin-wide change in outputs relative to the baseline ($\text{xtot}_{\text{avg}}(i,t)$ not xtot(i,d,t)).
- $\text{C}_{\text{com}}(i,d,t) - \text{C}_{\text{avg}}(i,t)$ indicates the change in costs of composite outputs (dry-land plus irrigated) relative to basin-wide costs for each farm commodity.
- $\text{C}(i,d,t) - \text{C}_{\text{com}}(i,d,t)$ indicates the change in specific dry-land or irrigated costs for a commodity relative to overall composite output costs. That is, if irrigated dairy production costs in the Murray NSW region rise in each year relative to overall dairy costs in Murray NSW in each year, then $\text{C}(i,d,t) - \text{C}_{\text{com}}(i,d,t)$ is greater than zero for irrigated dairy production in Murray NSW in each year.

While Dixon *et al.* (2011) obtained a tight fit of (A2) using modelled solutions, we do not obtain quite the same fit in this study. There are two main reasons. First, Dixon *et al.* considered only regions of the southern basin, between which water trading is permitted. On this basis, a single price applied to all irrigators in the southern basin. Second, the shocks we ascribe to water users vary in proportion from region to region. Nevertheless, by examining cost impacts, we are able to explain the outliers.

We consider the example of grapes. In several regions, output of grapes rises relative to the baseline. This is an unexpected result, given that we model grapes with fixed capital and consequent relatively rigid adjustment. In turn, we expect the rising price of water to drive down grape output. This is true for the basin in aggregate, but not for all regions within the basin.

In Figure A2.1, we see that grapes output in Murray NSW rises relative to the baseline. This is driven by a collapse in land rentals in the region due to environmental sales of water. The production costs of grapes in Murray NSW still rise relative to base, but by a smaller percentage than in other reasons. The key to the region's gain is in comparative costs, the a_2 term shown in (2). The fall in the costs of grapes production relative to other basin regions is sufficient for grapes production to rise relative to the baseline. The project impact, however, remains relatively modest, amounting to a 6.6 percent increase relative to base. Commodity price changes over time, driven by the exchange rate and global wine market conditions, are likely to have a bigger impact on grapes production in Murray NSW than water sales to the Commonwealth.

Figure A2.1: Grapes, % change relative to the baseline (year 2020)



A3. Explaining water prices as a function of annual allocations, drought and commodity prices in the southern basin

According to TERM-H2O results, the price of irrigation water is highly sensitive to drought conditions and moderately sensitive to the volume of irrigation water allocated each year. The model also predicts that a strengthening of farm output prices will lead to a hike in the rental of farm factors, including the water price. We are able to check whether these predictions align with observed data.

Table A3.1: Data used in irrigation water price regression

	\$/ML $P_{wat,t}$ (1)	GL (2)	drought index (3)	P (output) (4)
2001-02	35.00	7,477	0	102.7
2002-03	364.02	4,856	1.0	101.5
2003-04	66.63	5,551	0	97.2
2004-05	60.03	5,622	0	96.0
2005-06	57.25	6,585	0	100.0
2006-07	440.59	3,639	0.75	115.4
2007-08	562.16	2,682	0.4	129.8
2008-09	338.57	2,703	0.5	114.9
2009-10	153.52	4,237	0	111.4

Sources: (1) Watermove; (2) NWC data scaled to ABS and authors' estimates; (3) Bureau of Meteorology; (4) ABARES Commodity Statistics 2010.

We do so by estimating a regression of observed prices against explanatory variables, based on Table A3.1 data. Column (1) shows the price of irrigation water ($P_{wat,t}$),[7] (2) the allocation of irrigation water ($V_{alloc,t}$) in the southern basin and (3) a drought index D_t, based on observed rainfall deficits for the nine month period March to November (i.e., the index for 2007-08 is based on the rainfall deficit for March to November 2007). Column (4) shows a price index of farm outputs ($P_{farm,t}$), based on ABARES indexes, modified to reflect production weights in the basin. We use (2) to (4) to explain variations in the price of water:

$$\underset{\text{(t-stat)}}{\log(P_{wat,t})} = \underset{(2.97)}{1.629} \underset{(-4.41)}{-0.129}{*}V_{alloc,t}/1000 + \underset{(7.04)}{0.568}{*}D_t + \underset{(2.354)}{0.009}{*}P_{farm,t} \quad R^2=0.98 \qquad \text{(A3)}$$

In (A3), each of the coefficients on the explanatory variables has the expected sign. As water allocations increase, the price of water falls. The presence of drought imposes dramatic upward pressure on the water price. The coefficient on farm output prices is positive.

The alignment so far of TERM-H2O results with actual data is encouraging. As part of further model calibration, our next step will be to run TERM-H2O ascribing dry-land productivity shocks and water availability shocks year-by-year in the southern basin, using the data in columns (2) to (4) of Table A3.1 as the basis of these shocks. The water prices and changes in the composition of farm output in the southern basin generated by this exercise will enable us to fine tune TERM-H2O, thereby moving from a qualitative to quantitative checking of the model's performance.

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[7] This is based on data from the Goulburn basin only. Anecdotal evidence indicates a close correspondence between prices across regions in the southern basin where inter-regional trading is possible.

A4. Tables corresponding to figures in main report

Table A4.1 corresponding to Figure 1 – MDB macro impacts (% change from the baseline)

MDB	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
H'hold consumption	0	0.00	0.10	0.19	0.22	0.25	0.27	0.30	0.32	0.34	0.36	0.37	0.34	0.31	0.28	0.26	0.24	0.22	0.20	0.18	0.16	0.14
Investment	0	-0.00	-0.01	-0.03	-0.04	-0.06	-0.09	-0.12	-0.16	-0.19	-0.22	-0.25	-0.28	-0.29	-0.30	-0.30	-0.31	-0.31	-0.32	-0.32	-0.33	-0.34
Real GDP	0	-0.01	-0.02	-0.02	-0.03	-0.04	-0.06	-0.08	-0.10	-0.12	-0.14	-0.17	-0.18	-0.20	-0.21	-0.22	-0.23	-0.24	-0.25	-0.27	-0.28	-0.29
Employment	0	-0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10
Capital stock	0	0.00	0.00	0.00	-0.00	-0.00	-0.01	-0.01	-0.02	-0.03	-0.04	-0.05	-0.07	-0.09	-0.10	-0.12	-0.13	-0.15	-0.16	-0.17	-0.18	-0.20

Table A4.2 corresponding to Figure 2– Average MDB water price (2008 dollars per ML)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Baseline	26.0	28.0	30.1	32.2	33.7	35.9	37.7	39.3	39.6	39.6	41.0	43.2	44.8	47.0	49.3	52.6	55.5	57.5	59.7	65.1	67.4	69.6
Policy	26	33.0	41.0	47.5	54.0	62.1	69.9	77.7	83.5	89.0	97.7	108.7	113.7	119.6	125.5	133.4	140.3	147.3	155.1	168.3	179.8	194.0

Table A4.3 corresponding to Figure 5– Basin farm output costs (% change relative to the baseline)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Cereal	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Rice	0	2.0	3.7	4.5	5.2	5.7	6.2	6.9	7.9	9.0	9.9	10.7	10.8	10.9	11.0	11.0	11.1	11.2	11.4	11.5	11.7	11.9
DairyCattle	0	0.2	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.4	1.6	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2
OthLivestock	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Cotton	0	0.2	0.5	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.3	2.4	2.4	2.4
Grapes	0	0.3	0.5	0.7	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.1
Vegetables	0	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.8	-0.8	-0.8	-0.9
Fruit	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
OtherAgriclt	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table A4.4 corresponding to Figure 6– Basin farm outputs (% change relative to the baseline)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Cereal	0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4
Rice	0	-1.7	-4.0	-6.2	-8.0	-10.0	-11.9	-13.7	-15.0	-16.2	-18.0	-19.9	-20.0	-20.2	-20.3	-20.5	-20.6	-20.7	-20.9	-21.6	-22.1	-22.7
DairyCattle	0	-0.5	-0.9	-1.3	-1.7	-2.1	-2.5	-3.0	-3.5	-4.0	-4.5	-5.1	-5.3	-5.5	-5.7	-6.0	-6.3	-6.5	-6.7	-7.0	-7.1	-7.3
OthLivestock	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.7
Cotton	0	-0.3	-0.6	-0.7	-0.8	-1.0	-1.2	-1.4	-1.6	-1.8	-2.0	-2.3	-2.2	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.4	-2.4	-2.5
Grapes	0	-0.3	-0.7	-0.9	-1.1	-1.3	-1.6	-1.9	-2.3	-2.7	-3.0	-3.4	-3.5	-3.6	-3.8	-3.9	-4.0	-4.2	-4.2	-4.3	-4.4	-4.5
Vegetables	0	0.4	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.7	3.8	3.9	4.0	4.0	4.2	4.4	4.5	4.7	4.9
Fruit	0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6
OtherAgriclt	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0

Table A4.5 corresponding to Figure 7–MDB-wide output (2008 dollars relative to baseline)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Dry-land	0	22	47	64	87	111	138	167	195	216	234	264	276	282	290	298	310	317	326	335	359	377
Irrigated	0	-30	-66	-90	-122	-157	-196	-238	-280	-313	-345	-393	-412	-428	-446	-467	-492	-505	-522	-547	-583	-613

Table A4.6 corresponding to Figure 8 – MDB macro impacts (% change from the baseline) – buyback proceeds exit basin

MDB	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
H'hold consumption	0	0.00	0.00	-0.01	-0.02	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.09	-0.10	-0.11	-0.12	-0.13	-0.13	-0.14	-0.14	-0.15	-0.16	-0.17
Investment	0	0.00	-0.01	-0.04	-0.06	-0.09	-0.13	-0.17	-0.21	-0.25	-0.28	-0.32	-0.36	-0.38	-0.38	-0.39	-0.39	-0.39	-0.40	-0.40	-0.40	-0.41
Real GDP	0	-0.01	-0.03	-0.04	-0.05	-0.07	-0.09	-0.11	-0.14	-0.16	-0.19	-0.22	-0.24	-0.25	-0.27	-0.28	-0.30	-0.31	-0.32	-0.33	-0.34	-0.35
Employment	0	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.14	-0.15	-0.16	-0.17
Capital stock	0	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.03	-0.04	-0.05	-0.07	-0.09	-0.11	-0.13	-0.15	-0.17	-0.18	-0.20	-0.21	-0.23	-0.24

Table A4.7 corresponding to Figure 9– MDB macro impacts (% change from the baseline) – buybacks + upgrades

MDB	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
H'hold consumption	0.02	0.01	0.13	0.24	0.33	0.35	0.36	0.40	0.45	0.44	0.45	0.46	0.42	0.40	0.37	0.35	0.33	0.31	0.29	0.27	0.23	0.20
Investment	0.51	0.30	0.76	1.35	3.08	2.85	2.10	2.39	2.88	1.40	0.87	0.52	-0.07	-0.10	-0.11	-0.13	-0.14	-0.15	-0.15	-0.16	-0.14	-0.14
Real GDP	0.01	0.00	0.01	0.02	0.06	0.05	0.03	0.04	0.05	0.01	-0.01	-0.03	-0.05	-0.06	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.13	-0.16
Employment	0.01	0.02	0.04	0.07	0.14	0.17	0.19	0.22	0.26	0.25	0.25	0.25	0.23	0.22	0.21	0.19	0.18	0.16	0.15	0.14	0.11	0.08
Capital stock	0.00	0.06	0.09	0.16	0.27	0.49	0.64	0.73	0.82	0.92	0.95	0.96	0.95	0.90	0.86	0.82	0.78	0.74	0.71	0.66	0.62	0.58

Table A4.8 corresponding to Figure 10– Average basin water price (2008 dollars per ML) – buybacks + upgrades

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Baseline	25.3	27.5	29.5	31.6	33.0	35.2	37.0	38.6	38.9	38.9	40.2	42.4	44.0	46.1	48.4	51.7	54.5	56.5	58.7	64.0	66.3	68.5
Policy	25.3	32.4	39.0	44.1	49.0	55.3	61.3	67.4	71.6	75.7	82.7	91.5	95.7	100.7	105.8	112.6	118.5	124.3	130.8	142.2	151.6	163.2

Table A4.9 corresponding to Figure 12– Basin farm output costs (% change relative to the baseline)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Cereal	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Rice	0	2.0	3.7	4.5	5.2	5.7	6.2	6.9	7.9	9.0	9.9	10.7	10.8	10.9	11.0	11.0	11.1	11.2	11.4	11.5	11.7	11.9
DairyCattle	0	0.2	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.4	1.6	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1	2.2	2.2
OthLivestock	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Cotton	0	0.2	0.5	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.3	2.4	2.4	2.4
Grapes	0	0.3	0.5	0.7	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.1
Vegetables	0	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.8	-0.8	-0.8	-0.9
Fruit	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
OtherAgriclt	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table A4.10 corresponding to Figure 13– Basin farm outputs (% change relative to the baseline)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Cereal	0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4
Rice	0	-1.7	-4.0	-6.2	-8.0	-10.0	-11.9	-13.7	-15.0	-16.2	-18.0	-19.9	-20.0	-20.2	-20.3	-20.5	-20.6	-20.7	-20.9	-21.6	-22.1	-22.7
DairyCattle	0	-0.5	-0.9	-1.3	-1.7	-2.1	-2.5	-3.0	-3.5	-4.0	-4.5	-5.1	-5.3	-5.5	-5.7	-6.0	-6.3	-6.5	-6.7	-7.0	-7.1	-7.3
OthLivestock	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.7
Cotton	0	-0.3	-0.6	-0.7	-0.8	-1.0	-1.2	-1.4	-1.6	-1.8	-2.0	-2.3	-2.2	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.4	-2.4	-2.5
Grapes	0	-0.3	-0.7	-0.9	-1.1	-1.3	-1.6	-1.9	-2.3	-2.7	-3.0	-3.4	-3.5	-3.6	-3.8	-3.9	-4.0	-4.2	-4.2	-4.3	-4.4	-4.5
Vegetables	0	0.4	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.7	3.8	3.9	4.0	4.0	4.2	4.4	4.5	4.7	4.9
Fruit	0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6
OtherAgriclt	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0

Table A4.11 corresponding to Figure 14– MDB-wide output (2008 dollars relative to baseline) – buybacks + upgrades

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Baseline	0	21	39	48	61	75	91	107	123	136	147	165	173	178	183	189	197	202	208	214	230	242
Policy	0	-30	-55	-69	-89	-110	-133	-159	-185	-203	-223	-253	-265	-276	-287	-301	-317	-326	-337	-354	-377	-397

A5. Calculating the asset price of permanent water entitlements

(from Dixon *et al.* (2011))

Dixon *et al.* calculate the price [PPerm(t)] that a farmer would need to receive in year t (t = 2009, …, 2016) to induce him/her to give up the permanent right to an annual allocation of one unit of irrigation water according to:

$$\text{PPerm}(t) = \sum_{y=t}^{\infty} \frac{E\left[P(y)\right] * E\left[S(y)\right]}{(1+d)^{y-t}} \qquad t = 2009, \ldots, 2016 \qquad \text{(B1)}$$

where

E indicates expectation;

P(y) is the price of water in year y;

d is the discount rate (assumed to be 0.08 reflecting 3 per cent inflation and a 5 per cent real rate of interest); and

S(y) is the share of water rights in year y that is in fact allocated.

In Dixon et al. (2011), the S(y)s in 2009, 2010 and 2011 were assumed to be 0.7. 0.8 and 0.9, reflecting drought conditions that have made delivery of full water allocations impossible. For 2012 to 2018 they set S(y) at one.

Dixon *et al.* assumed that the expected values for P(y) and S(y) are given as follows.

$$E[P(y)] = PS(y), \qquad y = 2009, \ldots, 2018 \qquad \text{(B2)}$$

$$E[S(y)] = S(y), \qquad y = 2009, \ldots, 2018 \qquad \text{(B3)}$$

$$E\left[P(y)\right] = PS(2018) * 1.03^{y-2018} * SF(y) \qquad y>2018 \qquad \text{(B4)}$$

$$E\left[S(y)\right] = S(t) \qquad y>2018,\ t \in \{2009, \ldots, 2018\} \text{ and } y = t+10*n \text{ for n a positive integer} \qquad \text{(B5)}$$

and

$$SF(y) = \begin{cases} 1 & \text{if } E[S(y)] = 1 \\ 1.4 & \text{if } E[S(y)] = 0.9 \\ 1.84 & \text{if } E[S(y)] = 0.8 \\ 2.4 & \text{if } E[S(y)] = 0.7 \end{cases} \qquad \text{(B6)}$$

Via (B2) we set expectations for water prices in 2009 to 2018 according to the simulated values [PS(y)] obtained in our policy simulation, that is with the buyback scheme in place. Via (B3) we set the expected allocation shares in 2009 to 2018 according to the values adopted in our simulation. Via (B4) we allow for 3 per cent inflation in the determination of expected water prices for years beyond 2018. We also introduce a scarcity factor [SF(y)] to reflect periodic droughts. As shown in (B6), in years in which the expected allocation share is less than one, the scarcity factor magnifies the expected price of water. The magnifications (1.4, 1.84 and 2.4) were calculated via simulations showing the effects on prices of reduced allocations. Via (B5) we assume that the pattern of droughts (and hence allocation shares) in the decades beyond 2018 repeats the pattern assumed for the decade from 2009 to 2018.

The following site provides price data on permanent entitlements: http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/market-prices.html. The data from this source indicate a fall in the price of high security entitlements since the end of the drought.

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