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Water Trading, Buybacks and Drought in the Murray-Darling Basin: Lessons from Economic Modelling

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The Centre of Policy Studies (COPS) is a research centre at Monash University devoted to economy-wide modelling of economic policy issues.

Water trading, buybacks and drought in the Murray-Darling basin: lessons from economic modelling[a]

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TERM-H2O, a dynamic, multi-regional model has become a useful tool for analysing water policy issues in the Murray-Darling basin. Available data indicate that farm factor mobility has been an important avenue of adjustment to sharply reduced water availability during drought. The regional impacts of water buybacks in the basin are much smaller than otherwise as a consequence of this mobility.

Key words: CGE modelling, irrigation, agricultural economics, regional economies.

JEL classification: C54, Q11, Q15.

[a] Draft chapter for a book on water issues being compiled by Uniwater and CEDA

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Introduction

Australian economists have long history of sector-wide modelling for agriculture and economy-wide modelling with an agricultural emphasis. Guise and Flinn (1970) investigated the optimal allocation of water in part of the Murrumbidgee Irrigation Area. Their main policy insight was that inefficient water allocations occurred through the lack of a market-driven pricing mechanism: the shadow prices on water in different uses varied widely. Starting in the 1970s, Australian economist developed economy-wide models with an agricultural emphasis. This enabled them to quantify the effects on agriculture of shocks from outside agriculture (e.g, a mining boom, Dixon *et al*. (1978)). In the ORANI model, Dixon *et al*. (1977) adapted the CET (constant elasticity of transformation) form for farm sectors devised by Powell and Gruen (1968). This theoretical attribute captured in the ORANI model reflects observed short-term flexibilities in the product mix of farms.

Several reforms emerged in the 1990s from the Council of Australian Governments (COAG) process. Until the 1990s, water trading occurred in Murray-Darling basin only in exceptional circumstances. Among the reforms, ownership of land was disentangled from water rights. A mature water trading system requires other institutional arrangements, including water trading services such as Watermove, established by Victoria’s Department of Sustainability and Environment in 2002. Whereas earlier modelling indicated the possibility for economic gains from improved water allocations, the possibility for maximising these gains arose from water trading, with the water price determined by market conditions rather than institutional judgment.

Hall *et al.* (1993) formulated a model of irrigated agriculture of 18 regions in the southern Murray Darling Basin to estimate the effects of water pricing and in particular, water trading. The study also assessed the impacts of a “water bank” which would buy water for environmental or urban purposes. The authors found substantial gains from water trading. However, a subsequent study showed that observed volumes of water trading were much smaller than modelled volumes (Hall 2001). This appears to reflect a learning process. In the 2002 drought, large volumes of water were traded, particularly away from rice production. The severe drought in effect made the potential gains from water trading obvious to irrigators. In the three year drought of 2006 to 2008 that affected the southern Murray-Darling basin, water trading was essential in delivering sufficient water to perennials (vineyards and orchards) as allocations fell.

Over the past decade, very detailed economy-wide models (in particular, TERM, The Enormous Regional Model) have been developed In the first application of TERM, Horridge *et al*. (2005) found that drought wiped 1.5 percent off GDP despite agriculture’s contribution to GDP being only 3 percent in total in a normal year.

In this chapter we overview some of the key findings from TERM modelling of water-related issues.[1] First, we outline the modifications made to TERM to model irrigation water issues in the Murray-Darling basin. We then outline the modelled regional economic impacts of removing water from irrigation production and diverting it to the environment. Starting with estimates derived from the model’s database, we explain how modelled outcomes are smaller than initial estimates. Given that environmental water buybacks started during drought, we regard it as important to compare the impacts of buyback with the impacts of

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[1] TERM was also used to explore bio-security issues (see Wittwer et al. 2005).

drought. Finally, we regress observed water prices against variables including water availability, a farm output price index and a drought index. The regression indicates that TERM-H2O results are defensible against observed data.

TERM applications

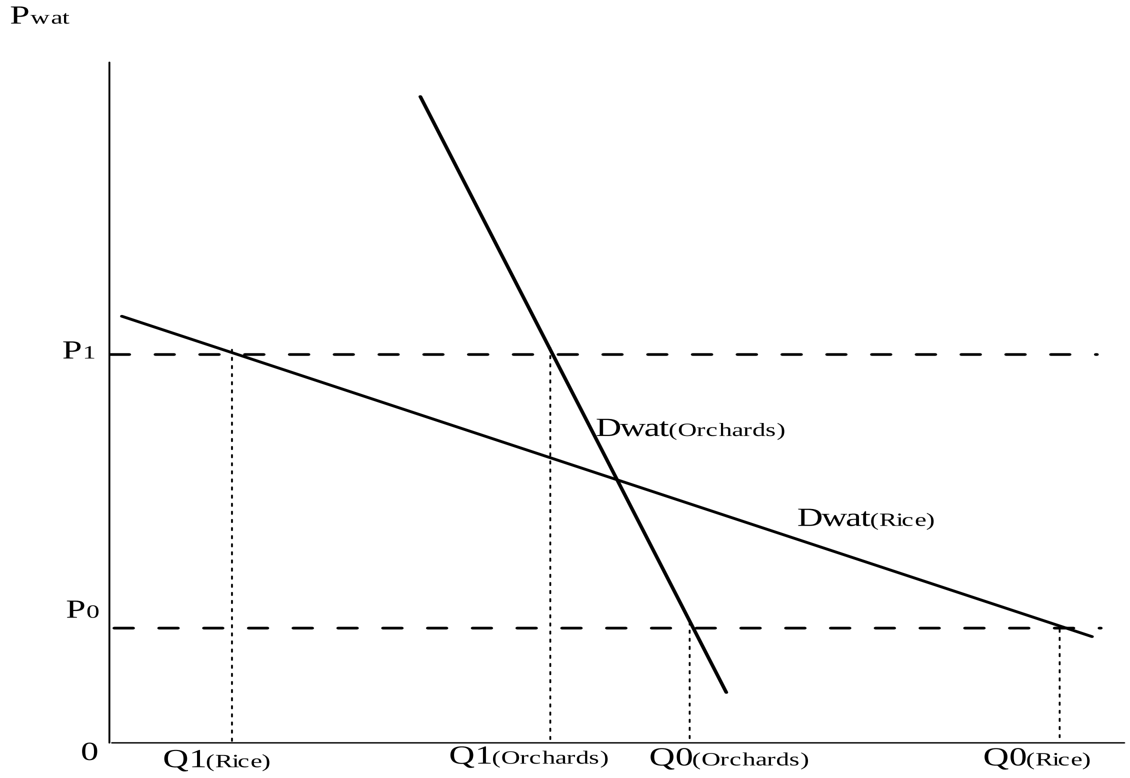
The first application of TERM performed well in explaining the negative income and employment impacts of drought (Horridge *et al*. 2005). Further enhancements were required for the model to become a useful tool for examining policy scenarios in the Murray-Darling basin. In this version (known as TERM-H2O), these included:

1. A split of farm sectors into irrigation and dry-land activities, with factor mobility between them;
2. Water accounts for irrigation sectors and water-trading possibilities;
3. A distinction between general purpose farm capital and specific capital.
4. Catchment level representation of basin regions; and
5. Dynamics.

One of the features of farming in the Murray-Darling basin, at least in annual cropping and livestock production, is flexibility. Annual cropping can respond to changes in water prices or relative output prices. Dairy producers can move between irrigated pasture, dry-land pasture and hand-feeding, depending on seasonal conditions and water scarcity. The first enhancement reflects this flexibility.

Since farm sectors are split into irrigated and dry-land activities, it is important to include water accounts in TERM-H2O for irrigated sectors (the second enhancement). Water accounts show the volume and price of water of each user in the database. These physical quantity data sit alongside the usual input-output value data in the CGE model. The average product of water varies widely between irrigation uses, so that as water availability changes, water use will change between irrigation activities. We see this in Figure 1. Perennials such as fruit orchards require a minimum amount of water each year. Therefore, as the price of water rises (from P_0 to P_1 in Figure 1), demand by orchards falls only slightly, from $Q_{0(Orchards)}$ to $Q_{1(Orchards)}$. This contrasts with rice, which has a relatively elastic response to the water price, since water accounts for a large cost share in total production even at relatively moderate price levels. In addition, rice is an annual, so that irrigators can move out of rice production towards other crops as the price of water rises. Therefore, in moving from $Q_{0(Rice)}$ to $Q_{1(Rice)}$ in Figure 1, rice moves from using more water than orchards to using less water than orchards in response to the same price hike.

Figure 1: Demand for water: comparing orchards and rice



In response to the shift in price shown in Figure 1, assuming that the cuts in allocations of rice and orchard irrigators are in equal proportions, rice irrigators would sell part of their allocation to orchard irrigators in the year of price P_1. TERM-H2O allows water trading between regions of the southern Murray-Darling basin, but is restricted to within-region trading in the northern part.

The third enhancement was to distinguish between capital that can move from one farm activity to another, and specific capital, such as an orchard or vineyard. This helps capture the difference in water price responsiveness of the orchard and rice irrigators, for example, as shown in Figure 1. That is, orchards have specific capital in the database but the rice sector has only mobile capital. Another enhancement was in a finer level of regional representation, at the statistical sub-division level. This enables us to represent catchment regions as in partial equilibrium models of irrigation water allocation.

Finally, TERM-H2O is a dynamic model. In dynamic modelling, we first run a forecast baseline, which is based on forecasts from various agencies of income growth, productivity growth and changes in commodity prices. Particularly in the case of water, for which the available volume and price vary more from year to year than for any other factor, there is considerable interaction between the baseline forecast and the policy scenario. For example, baseline water prices are much higher during years of drought than years of average rainfall. This in turn means that baseline conditions can have a marked impact on the welfare calculation in a scenario in which water is removed from production. Another example of a baseline condition that will affect impacts concerns commodity prices. If the baseline output price of one commodity starts to move down relative to other commodity prices, we would expect the output of that commodity to depress further the impact of buybacks on the output of that commodity. In particular, we might think of farm commodities in the USA that compete with Australian farm outputs. In the case of two perennials, citrus and winegrapes, US competition will increase as the Australian dollar strengthens relative to the US dollar. If we assume that a high exchange rate continues for many years in the baseline, we would expect Australian citrus and winegrapes output to decline over time. This in turn would reduce the water requirements of perennials, which may be important in the policy scenario.

Analysing the impacts of water buybacks in the southern basin

Dixon et al. (2011) analysed the impacts of farmers selling water to the Commonwealth from the southern basin. In the scenario, farmers eventually sell permanent entitlements equal to 23 percent of pre-buyback entitlements (Dixon et al. 2011, Figure 4). Using database weights, we can calculate a crude estimate of the impact on farm output. Irrigation accounts for 35 percent of farm output in the southern basin in the TERM-H2O database. If we assume that removing 23 percent of water reduces irrigation output by 23 percent, and there are no other effects, we would conclude that farm output in the basin would fall by 8.0 percent (=-0.23 x 35%). But this is wrong for three reasons.

First, irrigation water is not the sole source of water used in irrigation activities.[2] If we calculate the volume sold as a share of entitlements plus effective rainfall, the reduction in water supply shrinks to 18 percent from 23 percent. This reduces the estimated loss in farm output from 8.0 percent to 6.3 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 1, 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 (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 23 percent buyback scheme as a 1.3 reduction in farm output, not an 8 percent reduction as in the initial crude estimate.[3]

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[2] Rice uses 12 to 14 ML of irrigation water per hectare so the contribution of rainfall 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).

[3] Another way of thinking about the -1.3% result is to work out the reduction in the area under the demand curve for water implied by the buyback scheme; see Dixon et al. (2011), Fig. 4.

Table 1: Water use in the Murray-Darling Basin by activity (GL)

	2005–06	2007–08
Livestock pasture/hay/silage	2,571	997
-- Dairy cattle water usage	1,287	458
-- Dairy output index	100	74

Source: ABS (2008), Table 3.20; ABS (2009), Table 2.9.

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.

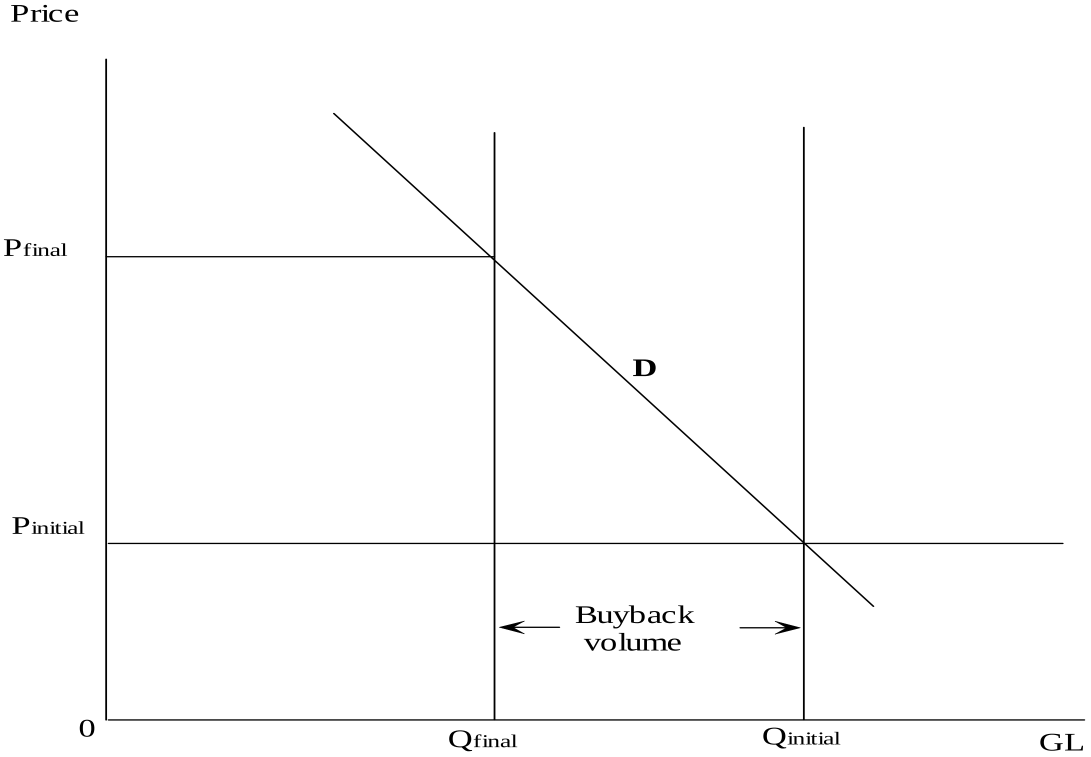
How would farmers fare without compensation?

A starting point for overviewing the impact of buybacks on basin regions is the idea that since farmers are fully compensated, any income losses will be offset by the annuity arising from buyback proceeds. That is, farmers will be no worse off with buybacks. Before exploring this point further, we examine the impact of buybacks on the income of farmers in Figure 2. As irrigation water is sold to the Commonwealth, denoted by a fall in available irrigation water from $Q_{initial}$ to Q_{final}, the price of water rises. In isolation, this is a windfall gain for farmers. For farmers who do not sell, the asset value of their water title will increase, denoted in Figure 2 by an upward movement in price from $P_{initial}$ to P_{final}. Does this mean that these farmers are better off?

We can predict that while the value of water assets will rise with buybacks, this will be offset by a decline in rentals on other factors. That is, with less water available per unit of other factors, the marginal product of other factors will decline. In the case of various forms of capital, stocks will adjust downwards over time in response to falling initial rentals, thereby gradually bringing rentals back towards base case forecast levels (i.e., levels they would have reached in the absence of buyback). Since farm land is fixed in aggregate, all the adjustment in land will be via rentals. Rentals on irrigable land will fall more than for dry land, but the latter will also fall. This is because irrigable land moves into dry land production as irrigation water availability falls, increasing the supply of dry land and thereby lowering its rentals.

One argument that has persisted in the environmental water debate is that the international competitiveness of farm output in the basin will be reduced as a consequence of buybacks. Our modelling predicts that increases in the price of water would be largely offset by reductions in the rental price of irrigable land. With these offsetting changes in factor prices, the international competitiveness of basin farming would be barely affected.

Figure 2: Market for irrigation water



There is considerable variation among farmers in the basin in both the mix of outputs produced and the holdings of various assets, including water and capital. Thus buybacks will have strongly differing effects across farm enterprises.

Thinking first of individual farmers, we can envisage that a rice farmer who owns large volumes of water entitlements is likely to gain from the buyback process, as the windfall gain in the asset value of water is likely to exceed losses in the value of other factors owned by the farmer. This contrasts with a grape grower, who is less able to sell off water as it is required to maintain volumes of water in the vineyard each year. A grape grower may own valuable capital (i.e, the vineyard) but may not own a large volume of water. The Lower Murrumbidgee regions contains both rice growers, who stand to gain from the buyback process, and grape growers, who may not be in the position to sell off water. This does make the grape growers worse off. Rather, it means that outside particular circumstances such as a looming retirement (either of the aging farmer or aging vineyard), or the opportunity to cash in on realised water savings over time, there may be little motivation for grape growers to sell water.

The Lower Murrumbidgee region may experience income gains due to the buyback process, even without including compensation payments. This is because the gains in the asset value of water holdings exceed losses from other factors. In TERM-H2O modelling of buyback scenarios, Lower Murrumbidgee ends up being one of the largest net exporters of water to other regions plus the Commonwealth. Net exporters of water benefit from the price hike in water. In the southern basin overall, based on the assumption that all buyback proceeds stay within the basin, aggregate household consumption increases slightly (0.34%) relative to forecast as a consequence of buybacks. We expect annuities to compensate farmers for a decline in farm output. That aggregate consumption rises above base case forecast levels reflects small terms-of-trade gains, as the demand curves faced by farmers for their output are not infinitely elastic. In practice, since some farmers may leave the basin, we might expect the impact of buybacks on aggregate consumption to be close to zero.

The distinction between drought impacts and buyback impacts

Lobbyists have asserted, despite the actions of farmers in voluntarily selling buyback water to the Commonwealth, that buybacks will be like a permanent drought. In response to this assertion, we present the direct impacts of drought and fully implemented buybacks respectively on dry-land productivity, rainfall and irrigation water availability.

Table 2 shows the direct impacts of drought as reported in Wittwer and Griffith (2011). A glance at the table shows that drought impacts are many-fold greater than direct buyback impacts. Buybacks do not reduce dry-land productivity, nor do they not stop the rain. Moreover, they are voluntary and fully compensated. In comparing columns (1) and (2) in Table 2, we see that drought is unambiguously worse than buybacks.

Table 2: Estimates of direct impacts of drought and buybacks on southern Murray-Darling Basin farming

	Drought 2007-08 relative to no-drought base case (1)	Fully implemented buybacks relative to base case (2)
Dry-land productivity[a]	-49%	0
Irrigation land: rain	-56%	0
Irrigation land: diverted water	-56%	-23%
Compensation	No	Full
Process	Involuntary	Voluntary

Source: Wittwer and Griffith (2011), Table 2.

a Change in dry-land productivity relative to a non-drought year.

It is not surprising therefore that the output and employment impacts of drought are many-fold greater than those for buybacks. For example, in the buyback scenario reported by Dixon *et al*. (2011), jobs in the southern basin fall 500 below forecast by 2018. In the drought scenario, 6000 jobs were lost relative to forecast during the worst of the drought, and due to the lost years of farm investment during drought, jobs remain 1500 below forecast a decade after full recovery from drought.

Wittwer and Griffith (2011) used database weights (i.e., the respective shares of dry-land agriculture and irrigated agriculture in total income in each basin region), multiplied by the drought-related shocks shown in column (1) of Table 2, to estimate the direct drought impacts within the southern Murray-Darling basin. Their database estimates were a GDP loss of 6.7 percent due to drought, with a 3.3 percent loss contributed by dry-land farming and a

3.4 percent loss contributed by irrigation sectors in 2007-08.[4] Water trading and other forms of farm factor mobility did much to reduce direct losses: the modelled loss in irrigation activity made a negative contribution of only 1.9 percent to regional GDP instead of 3.4 percent based on the initial calculation. In turn, due to movement of factors towards dry-land production, the GDP loss arising from dry-land production was only 2.7 percent instead of 3.3 percent.

Commentators often assert that regional multipliers result in a many-fold increase in direct losses. The version of TERM-H2O included a theory of excess capacity in downstream processing sectors, thereby allowing a partial closedown in such sectors in response to a worsening scarcity of farm outputs. Even with this theoretical enhancement to the model, output losses in non-farm sectors contributed only a further 1.1 percent to the overall GDP loss, which totalled 5.7 percent (=-1.9% (irrigation) + -2.7% (dry-land) + -1.1%(non-farm sectors)). Nevertheless, this income loss was large enough to reduce employment in the southern basin by 6,000 jobs relative to the base case forecast. Without water trading, the employment outcome would have been much worse.

Checking modelled outcomes against observed data

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 3: 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, using data shown in Table 3 for the southern basin. Column (1) shows the price of irrigation water ($P_{wat,t}$),[5] column (2) the allocation of irrigation water ($V_{alloc,t}$) in the southern basin and

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[4] The database weights in a drought scenario differ markedly from a normal year. In particular, the contribution of water to regional income increases due to relatively inelastic demand for water by irrigators. The respective shares of irrigation and dry-land activity in southern basin GDP are 6.1% and 6.7%. For irrigation, -3.4% = -56% x 6.1% and for dry-land, -3.3% = -49% x 6.7%.

[5] 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.

column (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 columns (2) to (4) to explain variations in the price of water:

$$\underset{\text{(t-stat)}}{\log(P_{wat,t})} = \underset{(2.97)}{1.629} \; \underset{(-4.41)}{-0.129} \ast V_{alloc,t}/1000 + \underset{(7.04)}{0.568} \ast D_t + \underset{(2.354)}{0.009} \ast P_{farm,t} \qquad R^2=0.98 \qquad (1)$$

In (1), 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 as expected.

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 3 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.

Concluding remarks

Models are a good discipline when it comes to checking exaggerated claims. Without models you can get away with saying anything. This has been evident during the buyback debate, as it was during the tariff debate of previous decades. In the earlier tariff debate, tariff cuts became the scapegoat for the impacts of a recession. Had Australia persisted with tariff protection, the nation would have been left behind, without, for example, access to cheaper and better cars. Concerning water, as a consequence of the prolonged drought of the previous decade, buybacks have been blamed for drought-imposed hardship within the basin. No modelling based on evidence-based assumptions has found significant job losses in the basin due to buybacks. TERM-H2O has supported arguments, for example, that buyback revenues are a useful source of funds for farmers during hard times. But modelling is only useful if the results can be explained and justified in terms of reliable data and realistic economic mechanisms.

One of the benefits in creating TERM-H2O has been to learn more about available data. Notably, changes in water use year by year give us insights into farm factor mobility in the basin. It is through the use of actual data that we have modified the theory of TERM-H2O so as to reflect producer behaviour better. Growers of annual crops are flexible: if the price of water rises, some producers will sell their water or divert it to other activities. In the case of perennials, water trading allows producers to buy in water. The theory of TERM-H2O distinguishes the relative inflexibility of perennial producers through the use of specific capital.

Some commentators have not been satisfied with modelling results which show that buybacks have relatively little impact on overall basin farm output. They turn to the notion of regional multipliers. Again, the evidence points to such multipliers being relatively modest. The same commentators argue, quite correctly, that house prices are likely to be affected by buybacks. However, they do not see the link between regional multipliers, a quantitative adjustment, and price impacts, which diminish these quantitative adjustments and consequent multipliers. Moreover, in some regions within the basin, the impact of buybacks on house prices could be positive.

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