The TERM-H2O modeling experience in Australia

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Abstract

This concerns CGE modelling development specifically on the Murray-Darling Basin in Australia. It outlines some of the key necessary elements for modelling. In particular, since farm production technologies in the basin are highly flexible, the supply side of a CGE model should reflect this flexibility. The bottom-up regions in the model are quite small, as it is important to distinguish regions between which water trading is possible from those in which such trading is not possible.

Water accounting is incomplete if it does not include the contribution from rainfall. If surface water allocated by managers does not change, but rainfall is in deficit, the price of water will rise. We will struggle to capture this effect in a model which does not include rainfall, reflected both in the initial conditions of irrigation water requirements and in the possibility to ascribe shocks to depict reduced rainfall.

Policy background

Australian farmers suffered one of the worst droughts in a century in 2002, followed by a severe record three-year rainfall deficit between 2006 and 2008. From a modeler's perspective, the drought-induced decline in farm productivity and irrigation water availability provided an opportunity to calibrate a CGE model with sub-national farm detail. The importance from a policy perspective of this calibration is that it provided a comparison of regional drought impacts with policy impacts.

The 2007 Water Act included a proposed program of voluntary buybacks of water rights from farmers and irrigation infrastructure upgrades. The policy objective was to restore the environmental health of the Murray-Darling Basin without undermining local economies. Inevitably, as drought induced a rural recession, buybacks were blamed for job losses.

The rest of this note concentrates on modelling issues concerning drought, in the context of a region which relies partly on irrigation water and partly on rain-fed agriculture, with considerable on-farm flexibility. References to Australia's buyback program reflect the coincidence of buybacks and drought.

Adapting the model to track observed impacts on farm outputs

The first ever application of the Australian TERM model was to the 2002-03 drought (Horridge et al, 2002). The modeling predicted a national GDP loss of 1.6%, a loss subsequently supported by national accounts data and about double that predicted by government agencies. Since the theory of the model did not include sufficient farm factor mobility, it underestimated the impact of drought on the most water-intensive crops. The droughts in the Murray-Darling Basin made it obvious that theoretical modifications were required to a "standard" CGE framework. Rice production almost ceases in drought, while cotton production falls dramatically. This implies flexibility in farm technologies in the Murray-Darling Basin. First, we need to add water accounts to our model. Then we need to revise the theory of the model to allow land, farm labor, capital and irrigation water to move from one output to another, depending on relative input and output prices. This enables us to move a long way towards being able to model observed dramatic drought-induced output changes.

Severe drought exposed another real life issue that had to be dealt with in TERM-H2O. The use of specific capital for perennials brings necessary inflexibility for these crops, which require a certain amount of water each year to stay healthy. But how do we treat livestock? Severe cuts in water allocations during prolonged drought meant that there was insufficient water to maintain both perennials and dairy herds, even after moving water away from annual crops. It so happened that dairy producers moved substantially from use of irrigated pastures towards feed-grain inputs during times of greatest water scarcity. TERM-H2O now captures this flexibility of farm production in the basin by allowing livestock producers to switch from irrigated land to feed-grain inputs. Specific capital in the livestock industries is mobile between the two technologies.

Plantation grubbing and herd culling would be much greater in drought without flexibility in water use or input substitution.

Towards appropriate regional representation

Water trading has been an important part of the response of farmers to changing economic circumstances and drought. However, although water trading between regions may be possible, it is important to keep regions sufficiently small so as to maintain realistic water trading possibilities. For example, the northern part of the Murray-Darling Basin includes far-flung tributaries between which water trading is not possible. So if we represent the northern basin as a single region with water trading between users within the region, we overstate water trading possibilities. A cotton grower on one tributary cannot trade with a dairy farmer on another. Regional disaggregation is an essential component in irrigation water modeling. In the context of the GTAP framework, this implies that sub-national irrigation industry representation is necessary.

What is the marginal contribution of irrigation water to the farming technology?

This is a universal issue, not confined to the Murray-Darling Basin in Australia. The mix of rain-fed and irrigation contributions to water usage in farming varies widely with crop type, average rainfall and seasonal conditions. A common omission in modelling irrigation farming is to include only irrigation water and not consider the rain-fed contribution. The simplest example shows us why this is deficient. In a drought, rainfall during the cropping season may be 200 mm below average. If this reduces effective rainfall by 2 megalitres per hectare, then an additional 2 megalitres of water are required per hectare from irrigation sources to make up the shortfall. During a drought spanning several years, irrigation cropping that relies on groundwater sources will draw increasing volumes from groundwater. This may be unsustainable. It may require drilling of deeper wells with rising pumping costs. It may in the worst of circumstances deplete an aquifer entirely.

Texas produces just over half of national U.S. cotton production. Around 120 Texan counties with a range of climates grow cotton. The largest contiguous cotton region is around Lubbock County, where rainfall and snowfall in the region provide less than half the water required for cotton production. Irrigation top-ups are depleting the Ogallala Aquifer. Between Pecos and El Paso in the far west of the state, the arid climate implies that cotton is almost entirely reliant on irrigated water. In the Rolling Plains region east of Lubbock, a slightly higher rainfall average reduces the reliance on irrigation. Similarly, the Blacklands region south of Dallas and the more humid Coastal Bend and Upper Gulf Coast regions are substantially rain-fed (Texas AgriLife Extension Service, 2009).[1]

If the rainfall in an irrigation area is highly variable, it may be useful to devise separate rain-fed and irrigation production technologies to produce the same crop. Dixon *et al*. (2012) elaborate this theory. Farm factors are mobile between different outputs, with specific capital for perennials and livestock herds reducing such mobility where appropriate. Specific herd capital may be mobile between pasture-fed and feed-lot technologies. The advantage of the Dixon *et al*. (2012) approach is that it captures a wide range of farming flexibilities – in a context in which water is tradable between irrigators and ownership of water is separate from ownership of land. Rice growers, for example, will cease to grow rice when the water price reaches the point at which is more profitable to sell water to other users than grow rice with it. Since the average product of water in rice production (which in the Australian context is almost entirely reliant on irrigation water) may be no more than $200 per megalitre, drought-

[1] See http://www.nass.usda.gov/Education_and_Outreach/Reports,_ Presentations_and_ Conferences/Presentations/Gregory_Beltwide09_MS_Statistics.pdf.

induced price rises in water reduce rice production quickly. In 2007-08, Australia's rice production fell to around 2% of what it was in 2005-06 (Table 1).

Table 1: Comparing modelled SMDB outcomes to observed changes

	Modelled outcome deviation from 2007-08 base (%)			Observed 2007-08 relative to 2005-06[b] (%)		
	Output[a]	Price	Water used[c]	Output[d]	Price	Water used[c]
	(1)	(2)	(3)	(4)	(5)	(6)
Cereal	-55.3	43.6	-78.8	-45.8	92.1	-9.9
Rice	-84.9	86.2	-90.7	-98.2	46.3	-97.8
DairyCattle	-13.6	29.5	-40.9	-26.5	52.0	-64.4
OthLivestock	-23.1	41.4	-44.6	-1.2	-9.2	-70.6
Grapes	-17.9	18.0	-49.0	2.7	44.6	-15.7
Fruit	-7.7	13.5	-23.1	9.3	7.3	-13.7
Vegetables	3.5	6.8	-1.4	21.8	14.9	-18.4
OthAgri	17.3	7.9	12.6	na	na	-27.0

a Value-added basis.
b Entire Murray-Darling basin.
c Water used in irrigation production.
d Value of output, not value-added.
Source: ABS catalogue no. 7125.0 ; Anderson et al. (2009); ABARES (2010).

Demands for farm outputs are down-sloping

Highly elastic demands do not enhance realism in modelling of drought. They may maintain the quiet life of modellers, but I have yet to meet a farmer who believes that farm output prices do not rise in response to drought-induced scarcity. We need to learn to deal with the perils of large drought-induced inward supply shifts during drought combined with down-sloping demand curves. The changes in price in Table 1 reflect a combination of local supply conditions and international demand conditions. The latter concerns mainly the biofuels boom prior to the GFC and growing demand for dairy products in China. These changes in international conditions are evident in the price increases shown in column (5) but not included in the deviation in column (2) of Table 1 for Cereal and Dairy Cattle respectively.

There is a danger in misinterpreting farm output data from drought. ABS data indicate that the Murray-Darling Basin's gross value of farm output *increased* between 2005-06, a normal year, and 2007-08, which was year two of a three year period in which there were record rainfall deficits in the basin. We need to recall national accounting conventions to respond to this statistic.[2] Water allocations to irrigators fell sharply between 2005-06 and 2007-08, so much so that dairy farmers could not afford to buy water to maintain pastures. Instead, some dairy farmers sold their entire annual allocation of water and relied on purchases of feed to keep their herds alive. That is, imports of feed-grains and hay were substituted for irrigated pasture. Dairy farmers with one third of their usual water allocation may have able to sell that water to perennial producers for 20 times the non-drought price. This may have been sufficient to fund feed purchases, implying that the dairy farmers were no worse off. But a perennial producer desperate to keep a plantation alive would have suffered a severe decrease in profits in order to pay for the water. Many orchards and vineyards were grubbed in response to drought. Even if gross farm output value rose during drought due to a sharp

2 If we assign weights to the outputs shown in Table 1, we will obtain an increase in the value of output from the "normal" year of 2005-06 to the drought of 2007-08.

increase in farm output prices, driven by local drought plus a pre-GFC biofuels boom at the time, there is little doubt that for many farmers, there was a sharp decrease in value-added output.

I cite this example to caution against overstating the impact of water trading. What is certain is that water trading in the basin helped farmers deal with the impacts of severe and prolonged drought. But it did not take away the hardship of drought, reflected in increased rates of foreclosures and other stresses, such as family break-ups and even suicides. However, it would appear that water trading provided the best way of responding to drought by enhancing the flexibility of farm factors in response to dramatic changes in supply conditions due to drought.

Comparing the regional impacts of drought and water buybacks

We can use calculations based on database values, productivity losses and falls in irrigation water availability to estimate the respective impacts of drought and water buybacks. It is clear from these calculations that the adverse impacts of prolonged drought on dry-land farm productivity and on irrigation water availability dominate the relatively modest output impacts arising from reduced water availability due to buybacks. Without factor mobility and without water-saving technological change, fully implemented buybacks would reduce real income in the Murray-Darling Basin by less than 1%. The comparable calculated impact of the 2006 to 2008 drought is a real income loss of 6.7% (Wittwer and Griffith, 2011).

TERM-H2O computes smaller losses in each scenario due to factor mobility. By entering the water market, the Commonwealth raises the asset value of water owned by farmers. This improves farmers' terms-of-trade. So although fully implemented buybacks result in basin income changing by -0.15%, regional real consumption grows by 0.3% relative to base (Dixon et al., 2011). Modeled long-run job losses in the region are fewer than 500 relative to forecast.

Farm factor mobility alleviates drought-induced losses, so that modeled farm output contributes -4.6% (not -6.7%) to regional income. But downstream processing and services contribute -1.1% to regional income, resulting in a total real regional income loss of 5.7%. Short-run regional job losses total 6,000. In the long run, the lost years of farm investment due to drought result in the regional job level persisting at 1,500 below forecast (Table 2, Wittwer and Griffith, 2011).

What is the main driver of the irrigation water price when it is tradable?

Table 2: Estimating explanators of the irrigation water price

	\$/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.
Reproduced from Table 7.5 of Wittwer and Griffith (2012).

Table 2 shows the key drivers of the irrigation water price in the southern Murray-Darling Basin between 2001-02 and 2009-10. This period included wide variation in all of the explanatory variables. Column (1) of Table 2 shows the price of irrigation water ($P_{wat,t}$).[3] Column (2) shows the allocation of irrigation water ($V_{alloc,t}$) in the southern basin and 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:

$$\log P_{wat,t} = 1.629 - 0.129 * V_{alloc,t}/1000 + 0.568 * D_t + 0.009 * P_{farm,t}$$

t-stat (-2.97) (-4.41) (7.04) (2.35)

R^2=0.98

In the regression, 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 and the coefficient on farm output prices is positive.

[3] 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.

We can compare water price predictions from the above regression equation with those of TERM-H2O. Each additional 1000 GL lowers the price by $53.60 per ML (southern Murray-Darling Basin only, 2005-06 ABS base). In Dixon *et al*. (2011), 1500 GL of water is sold to Commonwealth in the southern basin by 2018. The 2018 water price (i.e, when the policy is fully implemented) is $80/ML (in 2011 dollars) above the baseline. If we plug this reduction into the above regression equation, we get an increase in the water price of $80.40 ML [($VOL_{2007-08}$-$VOL_{2005-06}$) *-0.0536 =-1500 *-0.0536=80.4]. The regression equation and TERM-H2O predict similar water price increases arising from water buybacks. It is reasonable to infer that both may overestimate the price increase, as water-saving technological change may be accelerated in response to the policy.

The regression equation indicates that a drought of the magnitude of that of 2002 raises the water price by $232 per megalitre. Wittwer and Griffith (2011) modelled a water price increase of $285/ML in 2007-08 due to drought. We can plug the drought and water allocations for 2007-08 into the regression equation:

$$(VOL_{2007-08}-VOL_{2005-06}) \text{ x } -0.0536] + [D_{2007-08} \text{ x } 232.2])$$
$$=[(2682-6585) \text{ x } -0.0536] + [0.4 \text{ x } 232.2])$$
$$= \$302/ML$$

This shows us that the two quite different methods of estimating changes in water availability and rainfall conditions yield similar outcomes.

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