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Effective use of public funding in the Murray-Darling Basin: a comparison of buybacks and infrastructure upgrades

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Policy instruments designed to increase environmental flows in the Murray–Darling Basin are compared using TERM-H_2O, a detailed, dynamic regional CGE model. Voluntary and fully compensated buybacks are much less costly than infrastructure upgrades as a means of obtaining a target volume of environmental water, even during drought, when highly secure water created by infrastructure upgrades is more valuable. As an instrument of regional economic management, infrastructure upgrades are inferior to public spending on health, education and other services in the Basin. For each job created from upgrades, the money spent on services could create between three and four jobs in the Basin.

Key words: CGE modelling, regional economies, water buybacks.

1. Introduction

Council of Australian Governments (COAG) reforms introduced in the 1990s included important steps such as a cap on the volume of water extracted from the Murray–Darling Basin (MDB) and the separation of land and water ownership. The Water Act 2007 was an attempt by the Howard government to solve the problems of the Murray–Darling Basin. Infrastructure upgrades featured in the 10 point plan to address problems arising from water allocation in rural Australia announced on 25 January 2007. Points dealing specifically with such upgrades included the following:

1 a nationwide investment in Australia's irrigation infrastructure to line and pipe major delivery channels;
2 "a nationwide program to improve on-farm irrigation technology and metering; [and]
3 the sharing of water savings on a 50:50 basis between irrigators and the Australian Government leading to greater water security and increased environmental flows..."

Australian Government 2007, p. 1.

Other parts of the plan concerned the reduction in water allocations to farmers. Clearly, the Howard government was concerned about the regional

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economic implications of reducing irrigation water availability in the Murray–Darling Basin. Whereas $3.5 billion was allocated in the plan to buying water from farmers, almost $6 billion was allocated to infrastructure upgrades. The Murray–Darling Basin's proportion of proposed infrastructure funding is around four-fifths.

Buybacks entail full compensation at market prices and are voluntary.[1] However, infrastructure upgrades have been favoured by groups such as the Victorian Farmers Federation and National Farmers Federation.[2] In part, they are responding to communities who have been through difficult times with ongoing structural change and drought-induced job losses. The role of industry representatives is to emphasise the importance of their industry to regional economies. However, in their enthusiasm to exaggerate the potential losses arising from reduced water availability, such lobbyists have underestimated the adaptability and flexibility of farmers.[3]

Infrastructure upgrades enable farmers to use irrigation water more efficiently. But the expense of such upgrades is a major issue. Comparative costs are the problem: buybacks of permanent water entitlements so far have cost the Commonwealth around $2000 per ML, based on average expected annual allocations. Infrastructure upgrades cost between $5000 and $10,000 per ML.[4] Our argument concerns the balance of funding in the Water Act 2007, which may allocate more funding to upgrades than is socially optimal and too little funding to buybacks.

The economic argument for infrastructure upgrades appears to be even more tenuous when water accounting is based on net rather than gross extractions (Young and McColl 2009). Since some of the expected water savings are calculated as arising from reduced leakages, they may amount to an increase in net extractions of water for a given gross extraction. We model an increase of 240 GL of highly secure water to farmers despite this concern. On the other hand, irrigators may gain from improved timeliness-of-delivery

[1] A significant impediment to water trading concerns the fixed costs of delivery shares charged by water authorities. When an irrigator sells permanent water, he or she must continue to pay for delivery shares. In some cases, these fixed charges on an individual farm may exceed $100 per ML. Delivery shares are emerging as an area for substantial reform.

[2] Their submissions to the Murray–Darling Basin Authority are downloadable from http://www.mdba.gov.au/files/submissions/Victorian_Farmers_Federation.pdf and http://www.mdba.gov.au/files/submissions/National_Farmers_Federation.pdf.

[3] In early policy formation, it was unclear how the Commonwealth would implement sustainable diversion limits (SDLs). Prime Minister Gillard announced prior to the 2010 election that acquiring environmental water would be entirely through voluntary purchases by the Commonwealth. This should have alleviated concerns about uncompensated acquisition.

[4] Market prices for sales of permanent water are downloadable from http://www.environment.gov.au/water/policy-programs/entitlement-purchasing/market-prices.html (accessed 4 June 2012). Water volumes arising from infrastructure upgrades reflect earlier estimates by the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC), though subject to change. Infrastructure costs are based on the Water Act 2007 (Australian Government 2007, p. 4).

with irrigation upgrades. These are difficult to quantify but may extend additional effective water beyond 240 GL.

Using TERM-H_2O,[5] a Computable General Equilibrium (CGE) model of the Australian economy with a high level of regional and sectoral disaggregation of agricultural activity in the Murray–Darling Basin, we find that buybacks and infrastructure upgrades will have the following impacts:

1 The reduction in the volume of irrigation water will have a very small negative impact on national GDP (around one-fiftieth of one per cent, or $10 per person per year compared with business as usual), which may be considered as the cost of improving environmental flows in the basin. We do not account for the environmental benefits in the modelling;
2 During non-drought years, the value of water saved by investment in infrastructure is insufficient to offset the investment cost relative to buybacks;
3 In drought years, with greater water scarcity, the price of water is elevated and thus the value of highly secure water saved by infrastructure investment is greater, although still not sufficient to generate a positive net return on the investment; and
4 Upgrades to irrigation infrastructure represent a net inflow of funds to the Murray–Darling Basin region from the rest of Australia, with a short-term positive impact on gross regional product and employment in the MDB. However, this is not sufficient reason to support irrigation infrastructure upgrades. The funds could be used in the MDB region with three to four times the impact on jobs by investing in services in the region.

Detailed results for three scenarios ((i) *buybacks only*; (ii) *buybacks plus upgrades*; and (iii) *buybacks plus services*) in relation to two baselines (*no drought* and *periodic drought*) are presented in Section 4. Before presenting results, in Section 2, we review previous studies on water market reform in the MDB, and in Section 3, we describe innovations in TERM-H_2O, the economic model used in this paper. Section 5 contains concluding remarks.

2. Previous studies concerning irrigation water issues

Our economic analysis of the buybacks and infrastructure is built around four fundamentals: the economic impacts that are related to the reduction in availability of irrigation water; the transfer of funds from general government revenue to MDB farmers in the form of buybacks; the cost and economic returns to infrastructure investment and consideration of an alternative use for the funds; and the impact of periodic drought. Numerous economic impact studies take into account a subset of these factors. Using the CGE approach, this analysis is the first to take all four into account at the same time.

[5] TERM is an acronym for 'The Enormous Regional Model'. The H_2O suffix refers to a version of TERM specifically designed for modelling issues related to water.

In the past, the usual benefits of CGE models were overshadowed by a limited ability to represent catchment regions, as is highly desirable in a study of water issues in the Murray–Darling basin. The TERM approach to CGE modelling has overcome the spatial limitation (Horridge *et al.* 2005; Wittwer and Horridge 2010). TERM-H_2O combines catchment regions in the basin with composite regions depicting the rest of the Australian economy. By including an interface between catchment regions and the rest of the economy, TERM-H_2O enables the user to combine direct impacts that affect small regions, such as changes in water allocations with national influences such as movements in the real exchange rate. More detail on TERM-H_2O is given in Section 3.

The direct impact on agriculture of increased water scarcity has been addressed by numerous partial equilibrium studies (for example Eigenraam 1999; Hall 2001; Eigenraam *et al.* 2003, 2006). Griffith (2012) details the modelling effort over more than four decades. Such modelling influenced COAG reforms that started in earnest in the 1990s. A prevailing theme arising from these studies is that water trading plays a substantial role in improving allocative efficiency. Qureshi *et al.* (2007) concluded that gains from freeing up water trading could outweigh economic losses arising from taking water out of production. Against a background of increasing water scarcity, the introduction of water markets was a step in the right direction to reduce costs, notwithstanding institutional constraints and impediments to the operation of water markets.

A large body of economic modelling has accumulated on the impacts of removing water from the Murray–Darling Basin (Adamson *et al.* 2005; Qureshi *et al.* 2007; ABARES 2010a; ABARES 2011; Dixon *et al.* 2011; Grafton and Jiang 2011). Economic modelling by ABARES on behalf of the MDBA (Murray Darling Basin Authority) uses a two-stage process. The ABARES Water Trade Model (WTM) generates the effects of reduced water availability, taking into account trading of water. Regional impacts on GVIAP (Gross Value of Irrigated Agricultural Production) are fed into AusRegion, a comparative static CGE model of the Australian economy. ABARES finds that a reduction in irrigation water of 30 per cent leads to a reduction in gross value of irrigated output of around 15 per cent. Several other studies cited in ABARES (2010b), plus Dixon *et al.* (2011) based on TERM-H_2O, find a similar relationship between irrigation water and GVIAP. However, Dixon *et al.* (2011) show that reduced irrigation water availability leads to a movement of farm factors into dry-land production, with a partly offsetting increase in dry-land output.

Further work by Adamson *et al.* (2007, 2009) extends partial equilibrium analysis to deal with uncertainty, building in scenarios in which water availability varies as a result of variation in precipitation and climate change. However, the current study is the only general equilibrium analysis to incorporate periodic drought.

A stated aim of the Water for the Future program is 'considerable investment in more efficient irrigation infrastructure' (SEWPAC (Department of Sustainability, Environment, Water, Population and Communities) 2011[6]). The federal government reiterated its commitment to infrastructure spending in its response to the Windsor report (Australian Government 2011). While the engineering benefits of improved irrigation infrastructure have been quantified (SEWPAC (Department of Sustainability, Environment, Water, Population and Communities) 2011, see footnote 4), there is little quantitative research into the cost of infrastructure upgrades. While infrastructure investment is undoubtedly good for farmers in the MDB region, it does not follow that it is the best way to support the region. The loss of local services is raised as a concern by ABARES (2010a), yet the cost of infrastructure investment is not recognised as an opportunity cost to the MDB region. The need for more generalised support is made clear by a quote from The Windsor Inquiry into the Murray–Darling Basin Plan (House of Representatives Standing Committee on Regional Australia 2011):

> *'[to] change the discourse from one of taking water from Basin communities to one of investing in the long-term sustainable futures of those communities most impacted by water reform'.*[7]

The trade-off between water for irrigation and water for the environment has become highly topical (Griffith 2012). Returning water to the river system will have benefits to the environment that carry through to socio-economic benefits for Basin communities and the rest of the population. These are not taken into account in this study; we find that reducing the availability of water, a factor of production, is certain to have a negative economic impact. CSIRO (cited in MDBA (Murray Darling Basin Authority) 2012) estimates socio-economic benefits derived from improved environmental condition, including recreational and tourism benefits and reduced risk of adverse river or soil conditions. To proceed with the buybacks and/or infrastructure upgrades, there must be implicit acceptance that these benefits outweigh the costs.

3. Innovations in TERM-H_2O

TERM-H_2O includes a number of innovations which make it ideal for the analysis of water management policy. These are as follows:

- small-region representation in a CGE model;
- farm factor flexibility and water accounts in irrigation sectors;

[6] Submission 532 to the House of Representatives Standing Committee on Regional Australia (2011).

[7] C. Miller, Transcript of Evidence.

- dynamic linkages between investment and capital and between the national balance of trade and net foreign liabilities; and
- a dynamic baseline that includes periodic future droughts.

TERM-H_2O extends the small-region representation made possible by the TERM approach (Horridge *et al.* 2005). Small region employment data, gathered from the census coordinated by the Australian Bureau of Statistics (ABS), are the main source of regional estimates of economic activity in secondary and tertiary industries (Wittwer and Horridge 2010). Farm census data provide detailed crop and livestock output estimates at the small region level (ABS 2008).

TERM-H_2O was used by Dixon *et al.* (2011) in a comprehensive analysis of the buyback scheme. Important features of buyback scheme represented in TERM-H_2O are the effects of the reduction in irrigation water for agriculture and the impact of buyback revenue on regional consumption functions. TERM-H_2O was able to represent the production function with a highly disaggregated database and detailed nested production structure for many types of agricultural activity. This is described in more detail below, along with the consumption function.

The current results build on Dixon *et al.* (2011) in three ways: by adding infrastructure upgrades; by analysing an alternative use for the infrastructure funds; and by incorporating periodic droughts in the model's baseline. The remainder of this section is devoted to describing the agricultural production structure in TERM-H_2O, and two other important features of the model: its dynamics and baseline, and national and regional macroeconomic accounting.

3.1. Agricultural production

The production functions in a CGE model underlie the demand functions by industries for inputs of capital, labour, materials and, importantly in this study, irrigation water. Available data on irrigation water used in the Murray–Darling Basin indicate a high degree of flexibility in farm production. For example, in response to prolonged drought and reduced water allocations, water used in rice production fell by 69 per cent from 2001–02 to 2002–03, and by 98 per cent from 2005–06 to 2007–08 (ABS 2012). Since TERM-H_2O is primarily concerned with changes in water availability in the Murray–Darling Basin, it must include water accounts. Consequently, water is a factor in irrigation production in the model. Theoretical modifications are necessary to the core CGE theory of the model to reflect observed flexibility in water usage.

The standard approach in CGE model development is to start with input–output data. This provides the cost structure for each industry and the sales structure for each commodity. It also provides the initial solution of the model. The year of the database is 2005–06, chosen because it is a relatively typical year, unlike the 3 years of drought that followed. The published input–output table provided by the ABS contains only seven agricultural sectors, namely sheep, grains, beef cattle, dairy cattle, pigs, poultry and other agriculture (ABS (Australian Bureau of Statistics) 2009a,b). Our first task is to split other agriculture into more sectors. We base the split on published commodity details and agricultural output data (ABS 2010; ABS (Australian Bureau of Statistics) 2008, 2010). From these, we obtain input and output details for rice, cotton, grapes, vegetables, fruit and other agriculture.

We need to split some sectors into irrigated and dry-land production technologies in line with the theory outlined in the next section. Cereal, dairy cattle, other livestock, cotton, fruit and other agriculture are divided between irrigated and dry-land technologies. Rice, grapes and vegetables are treated as exclusively irrigated activities. Water used in dry-land activities is negligible: seasonal variations where applicable are captured by altering primary factor productivity. Water requirements in irrigated sectors come from a combination of natural rainfall and irrigation water.[8]

Following Horridge *et al.* (2005), we use regional shares data based on the agricultural census to split the national database into regions. Our next task is to use water accounts to obtain estimates of the value of water in gross operating surplus (GOS) (ABS (Australian Bureau of Statistics) 2012). To infer the value of water, we obtained prices from Watermove (see www.watermove.com.au). In some sectors, such as beef cattle and sheep, predominantly dry-land activities, water use accounts for a small share of total costs. At the other extreme, the value of sales of domestic unprocessed rice was \$265 million in 2005–06, requiring 1241 GL of water (ABS (Australian Bureau of Statistics) 2010, 2012). That is, the average product of water was only \$210 per ML, well below the average annual trading price of water in the southern Murray–Darling Basin for 2002–03, 2006–07, 2007–08 and 2008–09 (Wittwer and Griffith 2012; Table 7.5). Database preparation underlines the importance of devising a theory that makes rice production highly sensitive to water price rises. In 2005–06, the average southern basin price of water was \$57.25 per ML, implying that water in rice production cost \$72 million (Wittwer and Griffith 2012). Since there are fixed charges imposed by irrigation distributors, at this price, only about half of this water cost is subtracted from GOS. We assume that the rest is embedded in service inputs to rice production.

We assume that the output of farm industry (i, d)[9] is a Leontief function of an intermediate input composite and primary factor composite (Figure 1). The treatment of intermediate inputs is not shown in Figure 1. The

[8] As an example of the impact of natural rainfall on irrigation water requirements, ABS (2012, table 2.10) shows that rice in MDB required only 10 ML/hectare in 2010–11. More typically, it requires 12–14ML/hectare. The Bureau of Meteorology indicates that in the main rice-growing regions where most rice is grown, rainfall was at least 300 mm above average in the 9 months ending March 2011, in keeping with a reduced irrigation water requirement: http://www.bom.gov.au/jsp/awap/rain/archive.jsp?colour = colour&map = anomaly&year = 2011&month = 3&period = 9month&area = md.

[9] i refers to the industry's crop and irrigation status (eg cereal-irrigated) and d refers to the industry's region (eg Central Murray NSW).

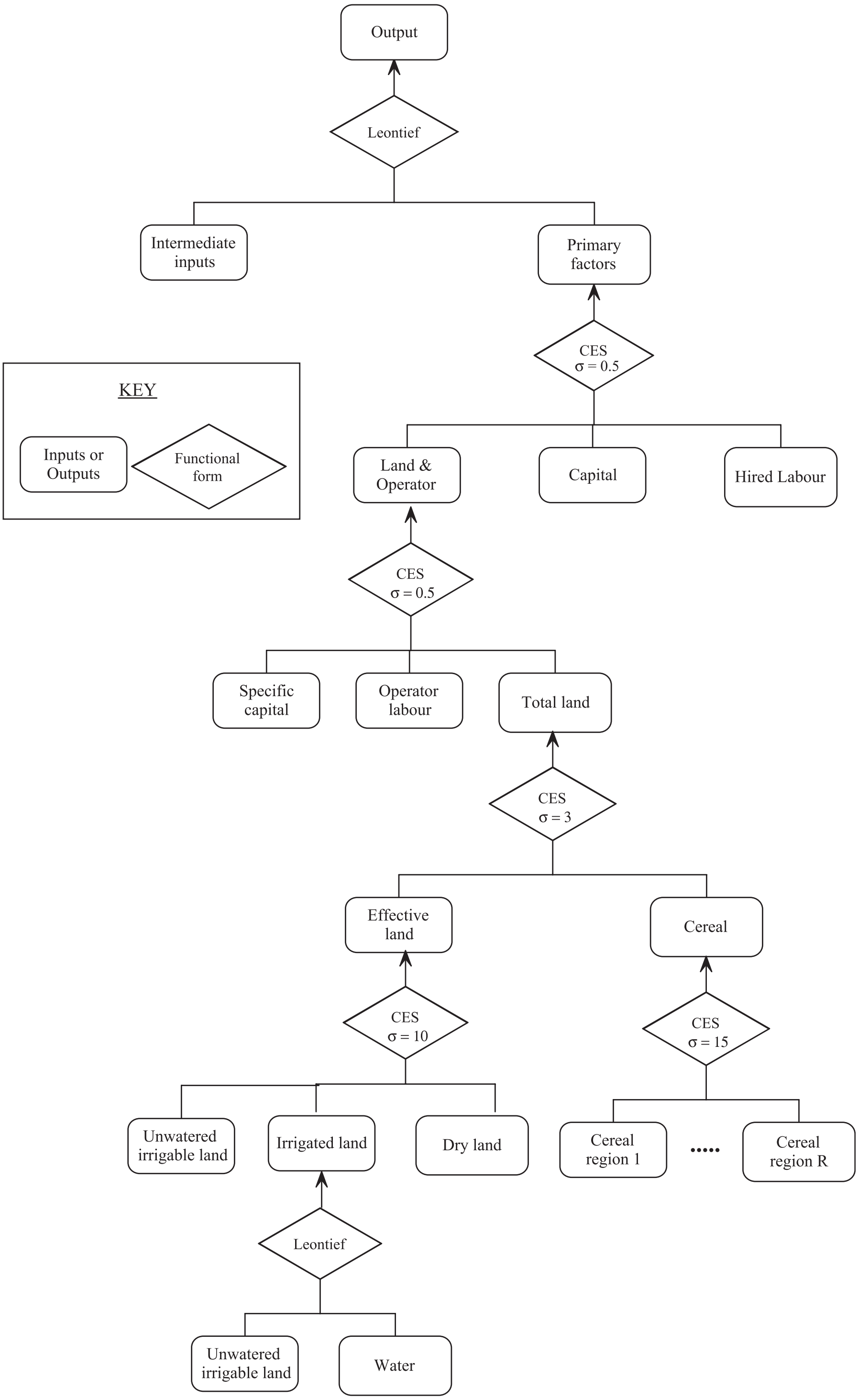

Figure 1 Production function in agricultural activities in TERM-H_2O.

intermediate composite is a CES (constant elasticity of substitution) combination of inputs of many goods. Each individual input is a CES combination of the imported and domestic varieties, while the domestic variety of good *i* is a CES combination of good *i* produced in each of the subnational regions.

The primary factor composite is a CES combination of three inputs: land and operator; general-purpose capital; and hired labour. A modification to the standard theory of MONASH-style models concerns the treatment of land and operator, part of 'mixed income' in ABS national accounts data. In earlier such models, there were no underlying inputs generating land and operator. In TERM-H_2O, land and operator is a low substitution CES nest of inputs of operator labour (the farmer and family), total land and specific capital. A CES parameter of 0.5 implies that demands for each of the individual factors tend to move together. For example, an increase in specific capital would also require an increase in operator labour and total land. Specific capital is relevant only for irrigated livestock (ie the herd) and irrigated perennials (ie orchards, plantations and vineyards), so specified as to limit factor mobility in these activities. In these industries, operator labour is applied to land that is 'improved' by the presence of orchards, vineyards and herds.

There are several nests below total land. The first makes total land, a CES combination of effective land and cereal (including purchased fodder). This nest is relevant only for dry-land livestock industries. We recognise that cereal is a substitute for land: a given amount of livestock can be maintained on less land if we use more cereal. A CES parameter of 3.0 between effective land and cereals enables substantial movements of livestock away from irrigated activities towards dry-land feed-lotting as the price of water rises. We assume that all cereal is domestically produced. For other industries, the use of cereals in our database is negligible, ensuring that total land is simply effective land. As with other domestically produced intermediate inputs, we model the input of cereal as a CES combination of inputs from the subnational regions.

Effective land is shown in Figure 1 as a CES combination of irrigated land, unwatered irrigable land and dry land. For dry-land industries, the use of irrigated land is negligible: in these industries, effective land is a CES combination of unwatered irrigable land and dry land. For irrigated industries, the use of unwatered irrigable land and dry land is negligible, so that effective land is simply irrigated land. The bottom nest concerns the input of irrigation water. We model this in a Leontief nest with unwatered irrigable land to form irrigated land. For a given crop, water use (a combination of irrigation water and natural rainfall) is constant per unit area unless we impose water-saving technological change.

Unwatered irrigable land appears twice, first in the nest below effective land and then in the nest below irrigated land. TERM-H_2O implies that a significant fraction of the available supply of irrigable land in any region is allocated as unwatered irrigable land to the region's dry-land industries when there are shortages of irrigation water. With reductions in water availability, TERM-H_2O generates increases in the prices of irrigation water and reductions in the rental values of unwatered irrigable land. These falling rentals result in dry-land industries increasing their demands for unwatered irrigable land. At the same time, irrigated industries suffer cost increases causing them to reduce their demands for unwatered irrigable land. A CES parameter of 10.0 implies that irrigated land can move easily into dry-land production as water scarcity worsens. In this way, unwatered irrigable land is moved from irrigated industries to dry-land industries.

We assume that each region *d* has available for year *t* fixed amounts of the factors irrigable land, dry land, operator labour and general-purpose capital. For each factor *f*, TERM-H_2O specifies supply to farm industry (i, d) as a function of the rental rate applying to factor *f* in industry (i, d) compared with the rental rates applying in other farm industries in region *d*. The supply functions for factor *f* in region *d* are derived from the optimisation problem: choose $Z(i,d,f)$, for all *i* to maximise

$$\sum_i \mathrm{PZ}(i, d, f) * \mathrm{Z}(i, d, f)$$

subject to

$$\mathrm{ZTOT}(d,f) = \mathrm{CET}_i(Z(i, d, f)) \tag{1}$$

where

$Z(i, d, f)$ is the supply of factor f to industry (i, d);

$\mathrm{ZTOT}(d, f)$ is a measure of the total quantity of factor *f* available in region *d*; and

$\mathrm{PZ}(i, d, f)$ is the rental price for factor *f* when used by industry (i,d).

Dixon *et al.* (2010) explain the above in greater detail.

Through CET equations, TERM-H_2O allows a reallocation of the fixed amount of factor *f* towards industry (i, d) and away from other farm industries in region *d* in response to an increase in the relative rental price of factor *f* in (i, d). The rental price applying to factor *f* in industry (i, d) then emerges from equating supply of *f* to (i, d) with the demand for *f* by (i, d) derived from cost minimisation subject to the production function described in the previous section. Relatively flexible activities such as cereals or rice use factors that can move readily to other activities in response to changes in relative rental prices. Relatively inflexible activities such as perennials and livestock include specific capital that makes relative price responses sluggish.

While the supply of general-purpose capital in region *d* within year *t* is fixed, it is allowed to change from year to year, following the Monash-style link between capital, depreciation and investment in $t-1$ (Dixon and Rimmer 2002). Investment in $t-1$ is modelled as a function of expected rates of return, reflecting mainly the rental price of general-purpose capital in region *d* in $t-1$. Supply of specific capital to industry *i* in region *d* is treated in a similar way to supply of general-purpose capital to region *d*. TERM-H_2O does not contain equations explaining movements from year to year in the availability to region *d* of irrigable land, dry land and owner-operator labour. In the simulations reported in this study, we treat supplies of these factors as exogenous and unchanged.

The Murray–Darling Basin's total supply of water (rainfall and irrigation water) in any year is exogenous. We assume that water prices are equalised across industries and regions through trade in the southern basin and across industries in each region elsewhere. In the case of intermediate inputs and hired labour, we assume that variations in demand by farm industries in the basin cause little change in prices; that is, we assume that these inputs are elastically supplied. National employment is exogenous.

3.2. Dynamics and baseline

A feature of dynamic models in the MONASH school is that a policy simulation consists of two runs: a baseline run and a policy run (Dixon and Rimmer 2002). The baseline run produces a forecast derived under business-as-usual assumptions. The policy run provides an alternative forecast inclusive of the policy shocks. Results are routinely reported year-by-year as accumulated deviations in the policy scenario from the baseline.

The dynamics within TERM-H_2O include linkages between current capital stocks and past investments at the industry level and between the balance of trade and net foreign liabilities. The linkage between capital and investment ensures that capital cannot be a free gift in the long run: investments drawn either from domestic savings or by borrowing from foreigners create capital in future periods in the model. The latter linkage ensures that the impacts of present investments on foreign borrowing are accounted for: investments that increase future earnings also increase net foreign liabilities. The calculation of the deviation in national welfare arising from the policy scenario accounts for changes in net foreign liabilities (see Eqn 4). This important feature ensures that infrastructure investment cannot be treated as a free gift to the nation.

The baseline is of particular importance in TERM-H_2O modelling. During drought, the marginal product of water increases many-fold in value. This implies that if water is taken out of production, as in a buyback scenario, the lost income from foregone water will increase many-fold during drought years relative to normal years. Indeed, the asset price of high security water reflects the expectation of one or two moderate droughts each decade. If in a non-drought year, the temporary price of water in today's dollars is \$50 per megalitre (ML), then the net present value of the water asset is \$1000 per ML based on a 5 per cent discount rate. In practice, permanent high security water has been priced at around \$1500 to \$2000 ML or more prior to the breaking of the prolonged drought of the previous decade. An asset price of \$1500 per ML is consistent with the expectation of two future droughts per decade that raise the temporary water price to about \$170 per ML in today's dollars without affecting allocated volumes. Since the asset price of high security water reflects the expectation of future droughts, we include hypothetical droughts in the baseline of TERM-H_2O.

3.3. Macroeconomic variables

Regional GDP in region *d* is calculated as:

$$\begin{aligned}\mathrm{GDP}(d) = &\sum_j \Big[\sum_g \mathrm{PZ}(j,d,g) * \mathrm{Z}(j,d,g) * (1+\mathrm{T}(j,d)) + \mathrm{PW}(d) * \mathrm{TRW}(j,d)\Big] \\ &+ \sum_c \sum_s \sum_u \mathrm{PUR}(c,s,u,d) * \mathrm{XPUR}(c,s,u,d) * \mathrm{TPUR}(c,s,u,d)\end{aligned} \tag{2}$$

where PZ(*j,d,g*) and Z(*j,d,g*) are factors as in Equation (1) plus hired labour, and *j* covers all and farm and nonfarm industries in region *d*;

T(*j,d*) is the production tax rate on industry (*j, d*);

PW(*d*) is the price of irrigation water in region (*d*); and

TRW(*j,d*) the volume of water sold by industry (*i, d*).

The expression on the second line of Equation (2) calculates indirect tax revenue of commodity *c* from source *s* (domestic or imported) by user *u*:

PUR(*c,s,u,d*) is the purchasers' price, XPUR(*c,s,u,d*) the quantity purchased and TPUR(*c,s,u,d*) the indirect tax rate on commodity *c* sourced from domestic/import source *s* by user *u* in region *d*.

A consumption function links household expenditure to regional income:

$$\mathrm{CON}(d) = \mathrm{GDP}(d) * \mathrm{APC}(d) * (1+\mathrm{SAPC}(d)) \tag{3}$$

where CON(*d*) is the regional aggregate household consumption; APC(*d*) is the average propensity to consume; and SAPC(*d*) is a shifter on the average propensity to consume, which we move after calculating annuities on buyback sales.[10] In summary, the macro accounting in TERM-H_2O includes two key components that may be missing from a partial model, namely net water trades on the income side and buyback proceeds in the household consumption.

When we measure welfare at the national level, we need to account for the policy impact on net foreign liabilities. We do so with a terminal calculation of the deviation in welfare (dWELF) at the national level:

[10] Since farmers are fully compensated for buyback sales, buyback proceeds should enter the consumption function in buyback scenarios. Cheesman and Wheeler (2012) report that after selling water to the Commonwealth, an overwhelming majority of farmers remained in the farming region. In TERM-H_2O, we shift the consumption function to reflect annuities arising from buyback proceeds, after calculating the asset value of water (see Dixon *et al.* 2011, appendix).

$$\mathrm{dWELF} = \sum_d \sum_t \frac{\mathrm{dCON}(d,t) + \mathrm{dGOV}(d,t)}{(1-r)^t} - \frac{\mathrm{dNFL}(z)}{(1-r)^z} \qquad (4)$$

where dCON and dGOV are the deviations in real household and government spending in region d and year t; dNFL is the deviation in real net foreign liabilities in the final year (z) of the simulation; and r is the discount rate.

4. Results

4.1. Scenarios

The *buyback only* scenario involves basin farmers selling water to the Commonwealth starting in 2009 and gradually increasing to 3500 GL in 2021. This represents approximately 30 per cent of full annual water entitlements. This is an earlier target volume that the Murray–Darling Basin Authority chose; the target has since fallen to 2750 GL. Should it become apparent over time that the regional economic impacts of water buybacks are relatively benign as modelled, the target volume may increase.

The *buyback plus upgrades* scenario includes \$3.5 billion (net present value, 2007 dollars) of infrastructure upgrades in the basin between 2008 and 2019 in addition to the buybacks. This scenario accounts for the cost of the infrastructure and subsequent water savings (see footnote 1).

To model buybacks in all scenarios, the exogenous water endowment available to irrigators in the basin is reduced, as water is sold in exchange for a lump sum that provides an annuity used to shift household consumption within the basin in Equation (3) (see Cheesman and Wheeler (2012) for survey evidence supporting this assumption). Infrastructure upgrades as in the *buyback plus upgrades* scenario entail investment to the utilities sector in TERM-H_2O with a consequent exogenous increase in the irrigation water available to farmers.

There are two variants of the two scenarios. The first variant assumes average rainfall years throughout the simulation period (*no-drought baseline*). The second variant assumes that moderate droughts occur twice a decade with consequent dry-land productivity losses and reduced rainfall (*periodic-drought baseline*). The judgment of water engineers is that infrastructure upgrades will create highly secure water. Since our drought scenario worsens water scarcity without reducing irrigation water allocations, this mimics the effect of highly secure water in drought. When completed, irrigation upgrades account for an additional 240 GL of water for farm use in all years, based on estimates provided by the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC). An additional volume of 570 GL is available to the environment, although not included in the modelling.

The *buyback plus services* scenario includes \$3.5 billion (NPV, 2007 dollars) of investment in public services in the basin instead of upgrades to irrigation infrastructure. This scenario captures the effects of the injection of funds into the MDB region, without the requirement that the funds are spent on irrigation. This scenario is run against the periodic-drought baseline. Services funding is modelled as exogenous increases in investments in public services in the basin. This increases capital stocks in basin services industries, with a consequent increase in employment in these industries. In effect, households become less reliant on inter-regional imports from state capitals and larger regional towns for services provision.

4.2. The no-drought baseline

Figure 2 shows the average price of water in the no-drought baseline, the *buyback only* scenario in which the Commonwealth purchases 3500 GL of water, and the *buyback plus upgrades* scenario which includes the same buybacks and an additional \$3.5 billion NPV of infrastructure upgrades in the basin between 2008 and 2019. With 3500GL of water removed from agriculture under *buyback only*, the price of water increases substantially. Infrastructure upgrades result in greater availability of water, exerting some downward pressure on its price.

The *buyback only* scenario consists of removing water from production. In Figure 3, we see the impact of the accumulated buyback volume for a given year on the price of water, with the price rising from P_{initial} to P_{final} as a consequence of an accumulated volume equal to the gap between Q_{initial} and Q_{final}.

Ignoring indirect tax income, income-side GDP consists of the sum of returns to primary factors over all industries (Eqn 2). A simple approximation to Equation (2) gives the decrease in real GDP to be equal to the area

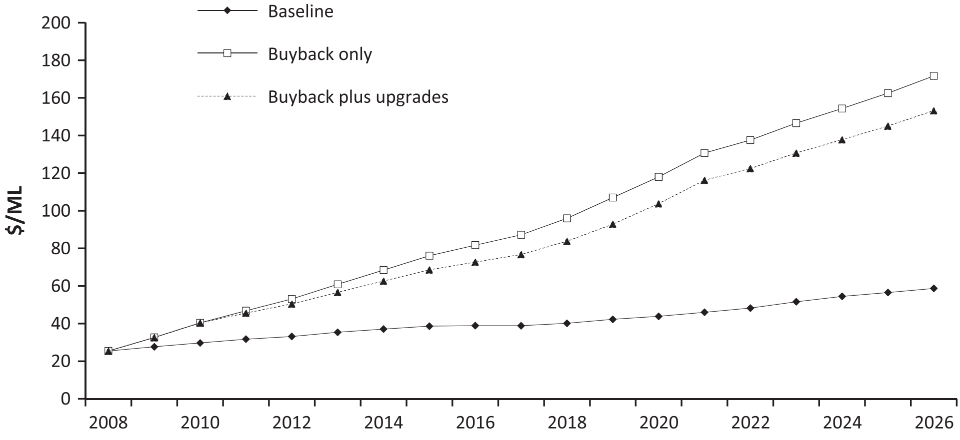

Figure 2 The basin-wide average price of water by scenario, *no-drought baseline* (2007 prices).

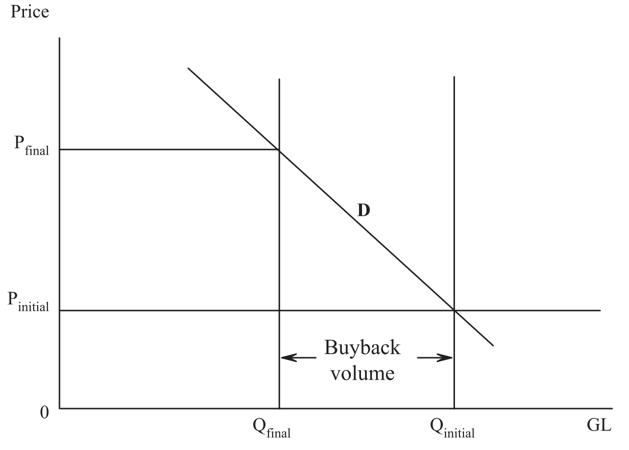

Figure 3 Market for irrigation water.

under the demand curve in Figure 3 between Q_{initial} and Q_{final}, assuming that the scenario changes no primary factor quantities used at the national level other than water. The percentage decrease in GDP is given by this area, divided by GDP and multiplied by 100, that is

$$-\%\Delta\text{GDP} = 100 * 0.5 * (Q_{\text{initial}} * P_{\text{initial}}/\text{GDP}) * (1 - Q_{\text{final}}/Q_{\text{initial}}) * (1 + P_{\text{final}}/P_{\text{initial}}) \tag{5}$$

The first bracketed term is the share of national GDP accounted for by value added from irrigation water in the MDB, around 0.02 per cent. The second bracketed term is equal to the proportion of water removed from production, that is, 30 per cent. The third bracketed term represents the increase in price attributed to buybacks, which is estimated to be 184 per cent above the baseline in 2021, that is $P_{\text{final}}/P_{\text{initial}} = 2.84$. According to this approximation, GDP in 2021 is 0.012 per cent lower than it otherwise would have been, as a result of buybacks.

The approximation in Equation (5) provides a simple check of the validity of the TERM-H_2O estimate, by identifying the removal of 30 per cent of irrigation water as main driver of the decrease in GDP. According to TERM-H_2O, by the completion of buybacks in 2021, the removal of 30 per cent of irrigation water accounts for a decrease in real GDP of 0.014 per cent. That the modelled change in real GDP is slightly worse reflects a small modelled decline in aggregate capital relative to forecast in the scenario.

Figure 4 shows the impact of both the *buyback only* and *buyback plus upgrades* scenarios on national real GDP. That the *buyback plus upgrades* decline in real GDP relative to forecast is larger than for buybacks alone reflects the excessive costs of infrastructure upgrades. The economic return to the investment falls short of the \$3.5 billion NPV cost. Admittedly, the modelling does not include the environmental benefit of the additional 570

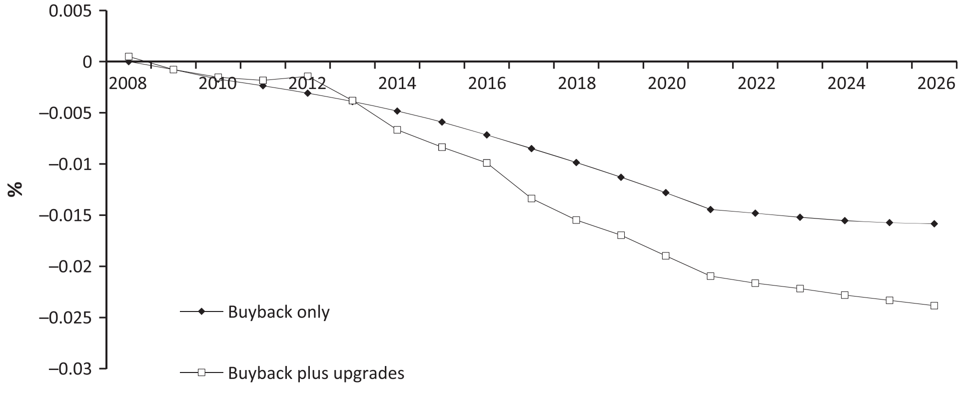

Figure 4 National real GDP (*no-drought baseline*) (deviation relative to forecast, %).

GL of water, although it would be cheaper to purchase the volume through an extension to the buyback process.

Using Equation (4), the welfare impact for the *buyback only* scenario is minus \$0.8 billion and for the *buyback plus upgrades* scenario, it is minus \$3.8 billion (2007 dollars, NPV). So far, the modelling results are consistent with economic orthodoxy: the infrastructure upgrades remain too expensive to be economically justifiable. Next, we examine the case in which there are several years of drought in the baseline.

4.3. The periodic-drought baseline

We represent drought by deterioration in dry-land total primary factor productivity, without any decrease in water allocations. Moderate drought is represented by decreases in rainfall of 20 per cent relative to an average year – this is relevant for the rainfall component on irrigated land. Dry-land productivity worsens so that for each unit of output, input requirements increase by 40 per cent. Both the rainfall decrease and dry-land productivity losses raise the value of the marginal product of water. Hypothetical drought years are 2014, 2015, 2021 and 2022. The increase in the price of water indicates the severity of the drought (Figure 5): our hypothetical droughts are less severe than the drought of 2007–08 when the price exceeded \$500 per megalitre (Wittwer and Griffith 2012).

From Figures 2 and 3, we see that the modelled price of water enables us to calculate the impact of buybacks on real GDP. We gather an approximate measure of welfare from national real GDP. Without droughts in the baseline, the *buyback plus upgrades* scenario is unambiguously worse than *buyback only*. However, the additional highly secure water arising from upgrades is much more valuable during drought than in normal years. Does the story change significantly if we include droughts in the baseline?

Figure 5 shows basin-wide nominal water prices and Figure 6 repeats the national GDP impact, with hypothetical drought years in 2014, 2015, 2021

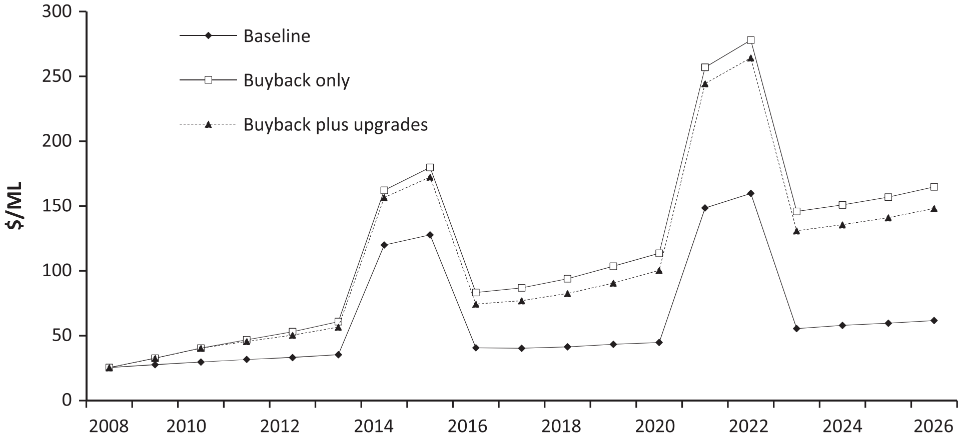

Figure 5 The basin-wide average price of water by scenario (*periodic-drought baseline*) (2007 prices).

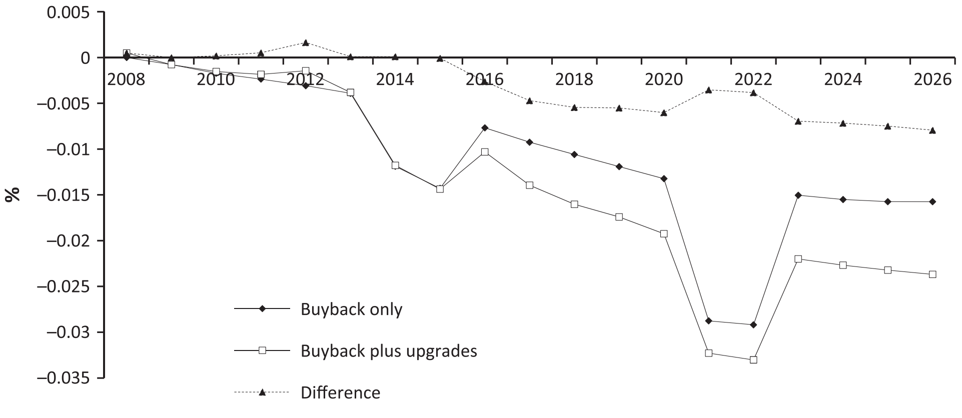

Figure 6 National real GDP (*periodic-drought baseline*) (deviation relative to forecast, %).

and 2022. The gap between the *buyback only* and *buyback plus upgrades* scenarios (Figure 6) remains similar to that of the scenarios with a no-drought baseline (Figure 4) in years without drought. But since the additional water available from upgrades is more valuable in drought, as is evident in the price hikes in the drought years shown in Figure 5, the gap in real GDP between the *buyback only* and *buyback plus upgrades* scenarios is smaller in drought years. Even in drought years, the *buyback only* scenario provides a better outcome.

4.4. *Buyback plus services* scenario

Using national GDP as a performance indicator for regional policy overlooks some of the redistribution effects of the policy. In the *buyback plus upgrades* scenario, the return on investment in upgrades is too low to offset the cost, leading to a negative effect on GDP. However, upgrades funded by the federal government are a windfall gain to the MDB regions at the expense of the rest of Australia. Upgrades represent an additional \$3.5 billion NPV of funds transferred to the MDB region, meaning that *buyback plus upgrades* outperforms *buyback only* in the MDB region in terms of GDP.

Advocates for the MDB region might support infrastructure upgrades on this basis, arguing that the cost to national GDP is small in relation to the impact on the MDB region. However, the benefit to the region eventuates because the infrastructure is provided at no cost: there is no evidence to support the notion that irrigation upgrades are the best use of a free injection of funds into the region.

In the *buyback plus services* simulation, the dollar amounts earmarked for irrigation upgrades are instead invested in services in the MDB. Figure 7 shows that while the upgrades to irrigation infrastructure provide a small increase in MDB GDP, the impact of investment in services is far more significant. The deviation in MDB's real aggregate consumption is shown in Figure 8, based on Equation (3). Real consumption outcomes are better than

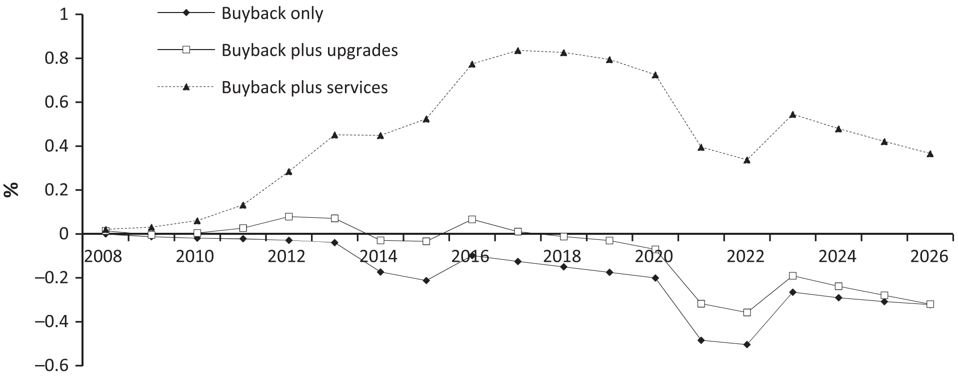

Figure 7 Real GDP in the MDB (*periodic-drought baseline*) (deviation relative to forecast, %).

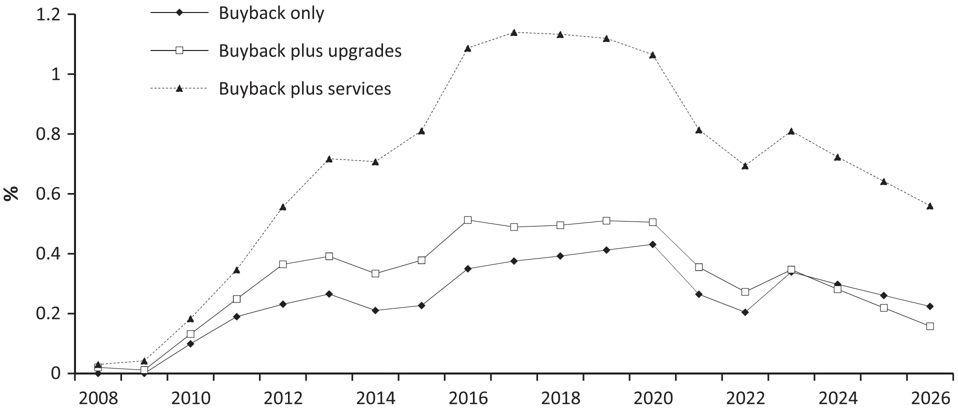

Figure 8 Real household consumption in the MDB (*periodic-drought baseline*) (deviation relative to forecast, %).

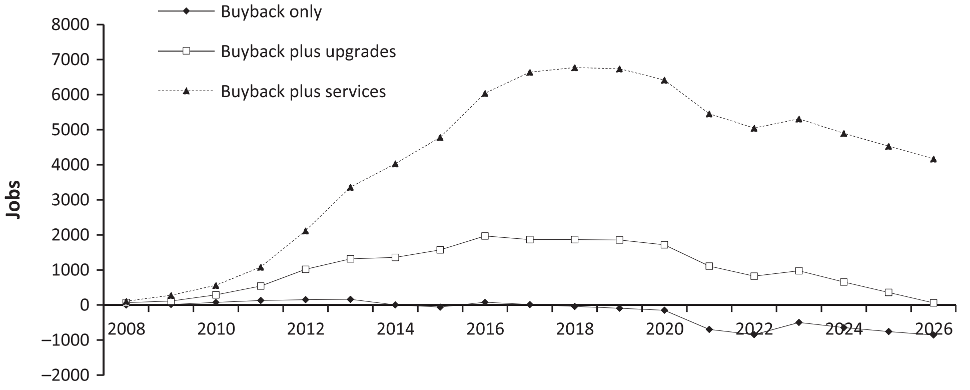

Figure 9 Jobs in the MDB (*periodic-drought baseline*) (deviation relative to forecast).

real GDP outcomes because annuities from buyback sales and small water trading terms-of-trade gains increase consumption as a share of GDP. We find that over 6000 jobs could be created in the region if the money were invested in services by 2016, around three times the jobs created by upgrades to the irrigation infrastructure (Figure 9).[11] In other years, the number of jobs created by funding services reaches up to four-fold or more relative to upgrades.

The attraction of upgrades to irrigation infrastructure as a form of compensation to the MDB region is substantially reduced when compared with alternative uses of the funds. However, to invest in other services is to forgo the 570GL in water available to the environment. This water could be added to the buyback scheme at a cost of between \$0.89 billion and \$1.14 billion based on current water asset prices (see footnotes 3 and 4), a significant saving compared with infrastructure upgrades, with a large compensation fund remaining for MDB communities.

Comparing the national welfare impacts based on Equation (4) with a *periodic-drought* baseline, *buyback only* results in a welfare change of minus \$1.1 billion, *buyback plus upgrades* results in a change of minus \$4.1 billion and *buyback plus services* in the basin results in a welfare change of minus \$1.1 billion (all NPV, 2007 dollars). The assumption is that services earn a normal rate of return.

The low rate of return on infrastructure upgrade investments drives the relatively poor outcome for the *buybacks plus upgrades* scenario. In an additional simulation in which water savings arising from infrastructure upgrades are assumed to be much larger, equivalent to 1700 GL in the basin, the NPV of the welfare outcome improves by only \$1.4 billion, still leaving a welfare gap between *buybacks plus upgrades* and other scenarios. The additional water has a diminishing marginal product, so that infrastructure investments with a NPV of \$3.5 billion remain excessive.

[11] The main barrier to funding services in basin regions is that it relies heavily on state funding, whereas infrastructure upgrades rely on Commonwealth funding.

4.5. Remaining arguments for infrastructure upgrades

Other arguments may persist concerning upgrades. Much irrigation infrastructure in the basin may be around 80 years old, aged, creaking and leaky. This does not mean that it is worth replacing. The economic foundations of basin irrigation suffer from the original sins of soldier settlement schemes established after both of the world wars. That is, left to market forces rather than economic planning by Commonwealth and state governments, irrigation schemes may not have been established on the scale that eventuated. However, once sunk capital such as irrigation infrastructure is in place, investments and labour tend to reflect prevailing market signals. If farmers are allocated water with little more than supply charges, and with limited opportunities to trade water, there may be no incentive to treat water as though it is scarce. Prior to the substantial COAG reforms, producer decisions may not have included water as a substantial variable input cost.

Part of the infrastructure upgrades undertaken by the Northern Victoria Irrigation Renewal Project (NVIRP) have been in the form of rationalisation.[12] That is, some channels have been decommissioned by buying the permanent water rights of farmers along the line. NVIRP has made a judgment that upgrades to parts of the irrigation network are not justifiable. Externalities arise from such rationalisation, in so far as if other irrigators sell their entire water entitlement, the costs of delivery rise for those who remain. Indeed, the last irrigator on a line may be forced to relinquish his or her entitlement, as the costs of water supply rise. If anything, this is a larger issue in the context of rationalisation of the irrigation network, as is happening under NVIRP, than in the context of buybacks: there is no requirement under the buyback scheme for irrigators to sell their entire entitlement. Such entitlements are readily divisible. This is consistent with farmers who wish to maintain a given scale of irrigation operations selling off part of their water title over time as water savings increase. However, farmers selling part of their entitlement may find that fixed delivery share charges in Victoria and exit fees in New South Wales act as barriers. These barriers point to the need for reform within irrigation authorities; they do not justify derailing of the buyback process.

5. Concluding remarks

The new contribution of this study has been to model the impact of infrastructure upgrades in the circumstance in which the additional water arising from such upgrades has a higher marginal value in some years. That is, the first runs depict *buyback only* and *buyback plus upgrades* in a sequence of years of average rainfall. Next, we model the respective runs in which there

[12] An example of a rationalisation agreement is downloadable from http://www.nvirp.com.au/downloads/Connections/Connections_Program/Sample_Legal_Agreement_R.pdf (accessed 4 June 2012).

are several drought years in the baseline, with no decline in effective irrigation water. The main finding is that drought indeed increases the value of such upgrades, based on the premise of highly secure water arising from upgrades, relative to years in which there is no drought. However, even in drought years, national real GDP is either worse or no better in the *buyback plus upgrades* scenario than the *buyback only* scenario (Figure 6).

If there were more droughts than normal years in the baseline, would it be possible to model a scenario in which the welfare outcome for buybacks plus upgrades exceeded that for buybacks alone? During a more severe drought, the performance of infrastructure upgrades would improve due to elevated water prices. However, in such a circumstance, investment in farming would fall over time (Wittwer and Griffith 2011). Infrastructure upgrades in this setting would slow the decline in farm investment. With many droughts in the baseline, farm output would be shrinking over time relative to a baseline without drought. On the other hand, by assuming that infrastructure upgrades yield much higher savings than modelled here, eventually such upgrades would outperform buybacks. In such circumstances, with higher returns from upgrades, farmers would be motivated to invest in such upgrades themselves rather than rely on public funding. Given the massive expense of proposed upgrades, the required water savings arising from them would need to be implausibly large to reach a break-even point of investment.

In the context of choosing between water buybacks or infrastructure upgrades, there is no need to attempt to monetise the environmental benefits. There appears to be broad acceptance in the community to sink substantial funds into the Murray–Darling basin. Indeed, the $8.9 billion allocated in the Water Act 2007 to the basin is equivalent to $588,000 per irrigator (Young 2011). At the heart of debate, once the need for substantial funds for remedial action is accepted, is how best to spend the money. Those who have lobbied against water buybacks have done so on the basis of economic impacts in communities. Following this line of argument, we find that were some funds earmarked for infrastructure upgrades redirected towards services such as health, education and aged care in basin communities, the community benefits would be greater. In the context of environmental restoration for which the funds have been earmarked, buybacks remain cheaper.

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