Modelling the impact of environmental policy reforms on water markets and irrigation use in Australia

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ABSTRACT

This paper explores the key factors motivating change in national, regional and local water institutions and examines how the resulting policy reforms affect water markets and water use. FEDSA-WATER, a national level CGE model of Australia is used to examine the removal of implicit subsidies on water usage in irrigation industries in New South Wales and Victoria, and the removal of small implicit taxes on usage in South Australia, for the various irrigation industries. A second scenario taxes producers for salinity. In the water pricing reform scenario, there is a redistribution of irrigation activity to South Australia with pricing reforms. There is an overall decline in agricultural output but this is outweighed by the benefit in terms of reduced salinity damage. Similarly, in the case of taxing producers for the full cost of salinity damage, the benefit of reduced salinity outweighs the reduction in national income.

Keywords: Water markets, externalities, salinity, CGE modelling.

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1. Introduction

Water and irrigation-related environmental pressures in Australia are greatest in the river system of the Murray-Darling Basin (MDB), which covers one-seventh of the country's landmass. The basin crosses four states, New South Wales, Queensland, South Australia and Victoria. It contains more than 75 per cent of the country's irrigated area and produces 90 per cent of the value of irrigated food crops. The MDB supports more than 50 per cent of the country's crop land and produces more than 40 per cent of the country's total agricultural output value (ABS 1996; MDBC 2001). In addition, the MDB is rich in Aboriginal cultural heritage sites and includes some 140 conservation areas and numerous internationally-recognised wetlands.

Some 95 per cent of MDB water diverted for human use goes to agriculture and the flows of all but one of the rivers within the system have been modified to support the growth of agricultural industries. At present, the level and rate of water diversions for irrigation have reduced the median annual flow out of the Murray Mouth by 80 per cent (MDBC 2001). Even though water is in short supply, misuse is widespread. Surface water quality in the MDB is deteriorating in key basins. Groundwater is being raised and is often polluted from surface sources and irreversibly damaged by saltwater intrusion. In other areas, overexploited aquifers are losing their capacity to hold water. Waterlogging and salinization are diminishing the productivity of irrigated lands. Decreasing water flows are reducing pollution assimilation and fish and wildlife habitat.

The purpose of this paper is to explore the key factors motivating change in national, regional and local water institutions and to use a national-level CGE model to examine how water markets and salinity taxes effect irrigators and agricultural output. The next section provides background to Australia's unique agricultural characteristics. Section 3 summarises the relative usage of irrigation water for different crops. A discussion of the motivation for policy reforms and the consequences of those reforms follows. The final section deals with modelling of water allocation reforms.

2. How is Australian agriculture different?

Irrigation trends in Australia are diverging from almost all of its OECD counterparts. The water used in Australia for agricultural purposes is increasing both in absolute and proportional terms. This contrasts with the experience of the European Union, Japan and North America where a decreasing proportion of water usage is for agriculture and an increasing proportion for cities and industries. During the past four decades, the area under irrigation in Australia has expanded six-fold. At the same time, the area under agriculture has increased by more than one-third, the average farm size has doubled in area and the volume of farm chemicals used has trebled (ABARE 1997a, 1997b, 1998, 2000; Chisholm 1997).

Australia's environment might explain in part both agricultural expansion and increased chemical usage: it is the driest inhabited continent. Hence, only 5 per cent of agricultural land has sown pasture grasses and less than 5 per cent is cropped. Although 60 per cent of the Australia's land area is used for agriculture, much is arid land used for grazing cattle and sheep on native grasses for meat and wool production. Nevertheless, there have been opportunities for agricultural expansion. Chemical usage has played an important part in allowing minimum tillage of shallow soils, especially in lighter rainfall areas that otherwise may not be suitable for cropping.

Agriculture remains more important to the economic prosperity of Australia than to most other advanced industrial countries. While primary agriculture's contribution to national production is not large, at around 3 per cent of GDP, the entire agricultural and food processing industry contributes 12 per cent of GDP and 7 per cent of employment (DFAT 1999; ABS 2000a).

Agriculture is expected to continue playing a significant role in regional economic development and as a foreign exchange earner. Indeed, 80 per cent of Australia's agricultural production is exported, the value of which accounts for one-fifth of all goods and services exports. While that one-fifth share is much smaller than in earlier decades, any downturn in agricultural exports still has important macroeconomic implications for Australia. That plus the high dependence of farmers on exports means Australia is unusually sensitive to policies and practices at home and abroad that affect its agricultural competitiveness. Indeed, increasing sales opportunities in the international market have motivated the expansion in many agricultural sectors.

Australia's expanded use of irrigation has occurred because it has relatively abundant water supplies compared with its major agricultural export competitors (Table 1). For example, compared with Australia's major wine exporting competitors, in per capita availability terms the country has 16 times more water than South Africa, 9 times as much as Italy, 6 times as much as France and Spain, and 2 times as much as Argentina. Australia has moved from a net importer of wine in the early 1980s to the largest wine exporter outside Western Europe since the late 1990s (Anderson and Norman 2001) Chile has more water per capita, three times that of Australia. In Australia, more than 70 per cent of water use is for agricultural purposes, compared with 12 per cent in France, 40 per cent in the US and 53 per cent in Italy.

Australia's lower population pressure and a rural sector generally free of polluting industrial activities provide irrigation-related advantages. The country's 19 million inhabitants are heavily concentrated in urban centres along the south-eastern and south-western coastlines, with most people living and working in cities. The country's eight state and territory capital cities account for two-thirds of the population and more than two-thirds of employment (SEAC 1996). Water use in many Australian cities declined and operational efficiency increased during the 1990s due to water reforms that led to higher prices and reduced subsidies (AATSE 1999).

The depreciating Australian dollar and increased product prices from growing export demand over the past few years have contributed positively to the profitability of irrigation activities in Australia. These have more than offset increasing expenses imposed by water reforms.

The downside of the positive picture for both dry-land agriculture and irrigation activities in Australia is that growing environmental concerns have arisen with expansion. In broadacre agriculture, large tracts of arable land are threatened by salinity. Irrigation has resulted in rising salinity, and has reduced water quality for downstream users, particularly so when coupled with excessive chemical usage.

3. Irrigation in Australia

Agriculture is Australia's largest water user, accounting for some 70 per cent of the country's water consumption (Table 2). The 2.1 to 2.4 million ha of irrigated crops and pastures represent less than 0.5 per cent of the total agricultural land and about 12 per cent of the total area of crops and pastures (Table 3). The value of irrigated production fluctuates between 25 per cent and 30 per cent of Australia's gross value of agricultural output (Cape 1997; ABS 2000b). Irrigation supports the production of all rice, most vegetables, milk, fruit, grapes, cotton and significant amounts of soybeans and sugar, while its contribution to meat, cereal, pulse and oilseed production is relatively minor (ABS 2000b).

Table 4 presents the gross value of product per ML of water use for specific crops. Vegetables, fruit and grapes are the high value water users, and pasture, rice, sugar and cotton are the low value users. Historically the price of water has been set so low as to not be a critical factor in the choice of crop under irrigation (Smith 1998). Much of this irrigated water still goes to low value uses. Figure 1 presents data from a 1997 benchmarking study of irrigation performance in NSW. Irrigated grape production out performs cotton, lucerne and rice: grapes averaged 3.4 ML/Ha and returned $6.45 per ML compared with cotton which averaged 7.5 ML/Ha and returned $0.58 per ML; lucerne which required 9.4 ML/Ha and returned $0.48 per ML; and rice using 12.8 ML/Ha and retuning $0.27 per ML. These numbers suggest a large potential for high value irrigation activities to draw water away from pasture, rice and sugar.

At the national level, pasture accounts for more than 44 per cent of irrigated area; cereals accounts for 23 per cent, and cotton 17 per cent. During the past decade, cotton and grapes have been two of the fastest growing irrigated crops (Figure 3). The irrigated cotton area expanded from 252 thousand ha in 1993 to 382 thousand in 2000. Irrigated grape production has expanded from around 43 thousand ha to an estimated 125 thousand during the same period. The total area planted to grapes in 2000 was 146.2 thousand ha, of which 85 per cent was irrigated.

NSW, Queensland and Victoria account for some 88 per cent of the water consumed in irrigation and 90 per cent of the irrigated area (Table 5). NSW dominates, consuming 46 per cent of the water on 44 per cent of the irrigated land. At the state level, average water use per ha varies from 2.2 ML/Ha in Tasmania to more than 20 ML/Ha in Western Australia.

4. Water policy reforms

Water-related environmental issues have become a key factor motivating change in Australia's water institutions. Water has moved to the forefront of national policy debates aimed at meeting expanding social, economic and environmental objectives. The primary agricultural activities causing water-related environmental problems are: (a) allowing runoff from fields to carry sediments, nutrients, organic matter and agricultural chemicals; (b) extracting too much water for irrigation, resulting in severe impacts on aquatic ecosystems, water quality and groundwater supplies; (c) inverting the natural pattern of river flows in southern Australia (high demands for irrigation during summer when river flows are low and low demand for irrigation during winter when river flows are high); and (d) clearing and using land and water in ways that result in rising water tables and salinity (Cullen and Bowmer, 1995).

The environmental issues arising from irrigation in Australia have become increasingly prominent over the past three or so decades, particularly with respect to the MDB. The world's largest toxic blue-green algal bloom in the summer of 1991-92 became an environmental crisis impossible for policy-makers to ignore. The algae expanded over a 1000-km stretch of the Darling River, resulting in the closure of water supplies and major disruptions to local communities. Superphosphate fertilizer used in the MDB has been singled out as the primary source of phosphorous feeding the algal outbreak. Local, state and national governments responded by establishing the Murray Darling Initiative.

To address problems associated with nutrient loads and eutrophication, increasing water salinity, declining wetlands and declining river health, the Murray Darling Basin Ministerial Council imposed a cap on water diversions in 1997. Establishing a cap involves the complex task of allocating water for environmental needs as well as for agricultural producers and other users. The cap on water diversions represents the most significant water resources initiative since the establishment of the MDB Ministerial Council in 1985. The council aims to balance economic and social benefits and the environmental uses of water in the rivers. The cap is defined as the volume of water that would have been diverted under 1993/94 levels of development. In unregulated rivers, this is expressed as an end-of-valley flow regime.

Historically, research and extension on sustainable irrigation practices and regulatory approaches have dominated Australia's policy response to environmental issues and resource mismanagement. But since the early 1990s, the regulatory approach has been complemented by or, in some cases, even replaced with economic incentives, market instruments and property rights systems (Corbyn 1996; Jones 1997; Gunasekera 1997). Policies are being developed for full cost resource pricing and overcoming market failure through the creation of property rights.

Market mechanisms introduced to meet strategic objectives include implementing the polluter pays, beneficiary pays and user pays principles. This more market-oriented approach also involves assessing total economic values for the costs and benefits attributed to environmental policies and government regulations, as well as the positive and negative externalities generated by agricultural production activities.

One major program drives water policies: the 1994 Council of Australian Governments (COAG) water reform agreement. Since the states and territories have prime constitutional responsibility for natural resource management, the COAG agreement attempts to integrate and coordinate water policies and avoid further fragmented efforts, policies and activities.

The aim of the COAG principles and guidelines is to reduce the use of government regulations and to encourage ‘minimum effective regulation’. An important objective is to sustain and restore ecological processes and biodiversity of water-dependent ecosystems. Regulations are supported only where a well-defined social or economic problem exists, where other solutions such as market mechanisms or self-regulation are inappropriate, and where expected benefits exceed likely costs.

Through COAG, the state/territory governments agreed to the following water policy reform strategy: water should be priced to reflect social cost and benefits; subsidies and cross subsidies should be removed; tradeable property rights would be established; and market mechanisms would be used to encourage more efficient management and use. In addition, COAG set out recommendations covering institutional reforms, environmental considerations, water-related research, taxation issues, consultations and public education.

The COAG water principles have spawned new water legislation in most states and territories. For example, South Australia’s Water Resources Act 1997 provides a comprehensive system of transferable water property rights, incorporates principles of ecologically sustainable development, establishes water for the environment, and devolves greater responsibility for water resources to local communities through the establishment of catchment management boards.

The New South Wales government established a framework of water reforms aimed at achieving a better balance in the sharing of water between the environment and water users to ensure long-term sustainability. Likewise, Victoria passed the Water Resources Act 1997 to amend the Water Act 1989 and to provide for similar COAG-induced reforms.

5. How are policy reforms effecting irrigation practices and land use decisions?

Rapidly changing water laws, water policies, water markets, licensing regimes, water administrations, and environmental regulations are altering the incentives and opportunities facing Australia’s primary producers. Australia’s water policy reforms are leading to higher water costs per unit of water used as the country moves to adopt the COAG water reforms. Volumetric restrictions in the MDB through the cap, as well as annual limits on groundwater dependent zones have restricted supply and raised substantially prices for water licenses.

Higher unit costs are expected in the future as further reforms are enacted and as market forces influence the price for water. For example, public irrigation system fees are increasing not only to cover operating expenses and capital costs of storage and supply structures, but also to cover refurbishment and replacement of depreciating infrastructure. Many irrigation structures are now at or near the end of their useful lives (Crabb 1997). In addition, irrigators are required to present farm management plans, pay environmental levies on water use, establish salinity prevention plans and to pay salinity fees when purchasing water.

As the volume of water used per irrigated crop declines, in many cases, so too does the total expenditure on water-related expenses. This is because producers conserve water by using less as its price rises. One way is through investing in new water-saving technologies. Other market incentives are also influencing water use. For instance, the trend among grape growers is to produce high-value grapes with concentrated juice by lowering yields. Keeping grape yields down means using less water. This trend implies even lower water requirements and higher returns per unit of water used.

There is little evidence in Australia that these higher short-term unit costs are imposing an enterprise-threatening situation, except for pasture. Even there, pasture producers are taking advantage of the higher water prices and selling some of their unused allocation, or selling their properties which are then put to higher value uses. Moreover, the dairy industry is restructuring due to deregulation and reforms implemented on 1 July 2000.

The evidence suggests that water entitlement transfers between irrigators have been from lower- to higher-valued commodities (Crabb 1997; ABARE 1999; Young *et al*. 2000). Investments in the wine industry, horticulture and the dairy industry in the state of South Australia, for example, are sending strong price signals. Banks are insisting that these developments be underpinned by secure water rights. From 1995 to 2000, water prices in South Australia's horticultural areas with access to Murray River water have increased from $500 to $1200 per ML. In some groundwater dependent areas with very thin water markets, water prices have been as high as $10,000 to $30,000 per ML in some cases. Dairy, rice and cotton producers are facing a greater cost-price squeeze than horticultural producers as overall subsidies to their industries are reduced.

Since 1995, grape growers in South Australia with access to River Murray water have expanded their vine area by 67 per cent, in response to increases in real prices of grapes for key varieties in all regions for seven consecutive vintages from the early 1990s (Wittwer 2000a). Grapes, especially premium grapes, are a relatively high value, low volume water user compared with other irrigation activities. Irrigation costs (including fuel for pumping costs and all related fees and levies) can range from 5 per cent to 15 per cent for grape growers. Grape growers can out-bid most other irrigation activities due to higher profit margins compared with other competing agricultural water uses.

A number of reasons help explain why higher unit water costs and increasing water delivery costs are not imposing problems for non-pasture irrigators (Stringer and Anderson 2001). One reason is that water costs are only a small proportion of total costs. In any case, alternatives are available to offset higher unit water costs and provide opportunities for cost-saving improvements.

Much more water is used in production processes than necessary, so many irrigators are able to make management changes to reduce their water consumption. For example, all current on-farm irrigation investments are much more efficient in water saving technologies than previous investments. Modern irrigation management systems use under-canopy sprinklers, mini-sprinklers, drip systems, centre-pivot systems that produce 'soft rain', laser land forming, soil moisture measuring equipment and efficient drainage. And the use of wasteful furrow irrigation is declining, from 50 per cent of the total irrigated area in 1976 to 20 per cent by the mid-1990s in South Australia (Crabb 1997).

Beyond horticulture, changes to improve water use efficiency are also taking place in the livestock sectors, such as replacing dams with piped reticulation systems for stock watering. Higher water charges over the past decade have encouraged water transfers out of low-value uses and locations. In addition, higher water prices have allowed irrigators to sell off part of their entitlement, invest the money in new water-saving technologies and then sell more of their entitlement (Young *et al.* 2000).

6. Adaptations to a CGE model to simulate water pricing reforms

In order to model possible impacts at a regional level of water allocation reforms, we have adapted a bottom-up, two-region model of the economies of South Australia and the rest of Australia. FEDSA-WATER is in the ORANI school of static CGE models (Dixon et al. 1982; Wittwer 2000). This CGE model includes four of the major irrigated crops -- pasture, cotton, rice and grapes.

On the output side of the model, the database, in addition to including the value of output of each commodity by each industry, has been modified to take account of environmental damage arising from production. For most agricultural industries, the initial value of environmental damage is set at 5 per cent of the total value of output. For rice, the damage is set equal to 20 per cent of the output value, given the high water demands of the crop, and for cotton, the corresponding figure is 30 per cent, reflecting the high use of polluting chemicals and fertilisers in production. The transformation parameter between agricultural outputs and environmental damage is set at 2.0 (since such damage is recorded as a negative value, outputs and environmental damage are complements in production).

In each scenario, we use a static long-run closure in which we assume there is sufficient time for capital to reallocate so as to equalise the rate of return across all sectors of the economy. Labour is mobile between sectors but the national endowment is fixed.

7. The scenarios

Our first scenario depicts the removal of implicit subsidies on water usage in irrigation industries in New South Wales and Victoria, and the removal of small implicit taxes on usage in South Australia, for the various irrigation industries. These subsidies are measured in terms of relative prices to irrigation users, rather than as social subsidies or taxes. We include the latter (in the form of environmental damage) in the transformation function of each agricultural industry in the model.[1]

[1] If we treat pre-reform water pricing as a combination of input taxes and subsidies on water usage in the specific industries we focus on, then removing these taxes and subsidies provides direct tax reductions to maintain revenue-neutrality. The result for real GDP is positive. But if we do not maintain

In 2001, prices for permanent water entitlements varied from around $400/ML in the pasture, cotton and rice producing zones of NSW, to $700/ML in the pasture and grape zones of Victoria, to more than $1000/ML in South Australia. Allowing trades across all state would reduce prices paid by South Australian irrigators and increase NSW prices. In each scenario, we assume that trades occur at $700 per Ml across the basin.

In the FEDSA-WATER model, agents respond to the changes in relative prices of inputs. In practice, there may be, at least in the short- to medium-term, a degree of inertia at least in some regions. Rice growers, for example, may perceive that their crop-specific capital, infrastructure and managerial expertise prevents them from cultivating other crops. To the extent that such inertia exists, particular regions may lose considerably from pricing reforms. Such losses may be greater than we model on the assumption of adjustments in labour and capital in each sector (although transfers of water rights may raise incomes in a region or sector as production declines).

The major focus is on the redistribution of activity between industries and regions with the pricing reforms, and with the impact of the pricing reforms on environmental damage. As we would expect, the irrigation industries in NSW (cotton, rice and irrigation pasture NSW) lose from the reforms. The costs of production for cotton rise by 2 per cent, for rice by 7 per cent and for irrigation pasture NSW by almost 13 per cent. Outputs in these sectors decline by 0.4 per cent, 1.1 per cent and 1.0 per cent respectively.

A surprising result is that grapes in Victoria lose. The main reason for this appears to be intra-domestic substitution: although the costs of production change little with the slight change to the price of water used in Victorian grape production, the costs of production of irrigated grapes in South Australia drop by almost one per cent. We assume a high degree of interstate substitutability of grapes between South Australia and the rest of Australia as inputs into wine. Consequently, some of the output growth of 1.2 per cent in South Australian grapes is at the expense of Victorian grapes, through a change in relative regional prices.[2]

In addition to a redistribution of activity from the rest of Australia to South Australia, there is also a small reduction in the overall output of irrigated industries with the price reforms. As measured in national accounts terms, there is a small increase in national welfare arising from the pricing reforms of $29 million.[3] The social benefit arising through reduced salinity damage is $24 million. The latter figure is sensitive to two sets of assumptions. The first is the proportional value of environmental damage arising from each type of agricultural activity. The second is transformation parameter choice.

The proportional value of environmental damage requires a closer examination of available estimates than we have managed to this point. We deal with parameter

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budget neutrality, by excluding the value of the implied net subsidy to irrigators, without allowing for direct tax reductions, real GDP decreases slightly when we introduce pricing reforms.

[2] At present, the model does not include the same substitutability between NSW grapes and those from elsewhere. To do so would reinforce the substitution effect, with larger gains for South Australia.

[3] Aggregate real consumption is used as the measure of welfare, with aggregate real investment, real government expenditure and the trade balance all exogenous.

choice to some extent, through the use of systematic sensitivity analysis (Arndt and Pearson 1996). In this analysis, we vary the transformation parameter from its base value of 2 by plus or minus 1.75 (with a uniform distribution) in order to obtain the estimated standard deviations shown in parentheses in Table 6. This scenario shows us that pricing reform has a positive effect on environmental externalities, mainly because we assume that the most environmentally damaging industries are those with the largest implicit subsidies for water usage.

Next, we go a step further and introduce taxes on each of the industries to reflect the environmental damage inflicted by them. In each case, the additional taxes are set approximately equal to the value of environmental damage assumed within the database. In each irrigated sector, the price of water moves from its present price inclusive of an implicit tax or subsidy to a price determined purely by the environmental damage. In the model closure, we assume that the additional revenue raised is used specifically to repair environmental damage, so that there is no direct tax reduction to offset the revenue from taxing environmental damage.

In all irrigated industries, outputs decline as the costs of production rise. The magnitude of these declines is small, given the very large cost hikes particularly for cotton and rice. It is possible that the aggregation of downstream industries in the database masks the extent of possible declines: more aggregated downstream industries will suffer smaller cost hikes if a primary product rises than in the case of more disaggregated industries, such as ginned cotton. With the decline in agricultural output, aggregate consumption decreases by $95 million, but the reduction in the environmental damage is $222 million, with a standard deviation of $72 million arising from varying the transformation parameters in agriculture by ±1.75.

8. Summary of modelling outcomes

In the water pricing reform scenario, there is a redistribution of irrigation activity from upstream to South Australia with pricing reforms. There is an overall decline in agricultural output but this is outweighed by the benefit in terms of reduced environmental damage. Similarly, in the case of taxing producers for the full cost of such damage, the benefit of reduced environmental damage outweighs the reduction in national income.

The direction of results did not change as the transformation parameter varied within the range discussed. Some of the most serious concerns with reforms to water pricing originate at a statistical division or sub-state level. A model with regional disaggregation to the statistical division level may provide additional insights. However, if producers of the most environmentally damaging or lowest-return-to-water-usage crops sell off water rights, they will be compensated to some extent for losses in production income.

Turning to sectoral disaggregation, the aggregation of food processing industries in the model's database may also mask some of the potential losses to primary activities whose costs rise with pricing reforms or environmental taxes. Even so, the introduction of user pays and polluter pays principles in irrigation industries may hasten the switch to water-saving technologies and minimise the use of polluting chemicals and fertilisers, without severely diminishing output in vulnerable sectors.

References

AATSE (Australian Academy of Technological Sciences and Engineering) 1999, *Water and the Australian Economy,* AATSE, Melbourne.

ABARE (Australian Bureau of Agriculture and Resource Economics) 1997a, *Australian commodities: Forecasts and Issues,* ABARE, Canberra.

ABARE 1997b, *Australian Commodity Statistics,* ABARE, Canberra.

ABARE 1998, *Australian Commodities,* September quarter, ABARE, Canberra.

ABARE 1999, *Irrigation water reforms: impact on horticulture farms in the Southern Murray Darling Basin*, Current Issues 99.2, ABARE, Canberra.

ABARE 2000, *Farmstats Australia,* ABARE, Canberra.

ABS (Australian Bureau of Statistics) 1996, *Australian Agriculture and the Environment,* ABS, Canberra.

ABS 2000a, *Australian Wine and Grape Industry*, Cat no 1329.0, ABS, Canberra.

ABS 2000b, *Water Account for Australia*, Catalogue no. 4610.0, ABS, Canberra.

ABS 2001, *Agriculture Australia*, Catalogue no. 7113.0 ABS, Canberra.

Anderson, K. and Norman, D. 2001, 'Global Wine Production, Consumption and Trade, 1961 to 1999: A Statistical Compendium,' Centre for International Economic Studies, Adelaide,.

Arndt, C. and Pearson, K. 1996, 'How to carry out systematic sensitivity analysis via Gaussian quadrature and GEMPACK', GTAP Technical Paper No. 3, Preliminary version, Purdue University, West Lafayette, May.

Cape, J. 1997, "Irrigation", in Douglas, F. (ed) *Australian Agriculture: the Complete Reference on Rural Industry,* Morescope Publishing, Melbourne.

Cato, L. 1995, *The Business Of Ecology: Australian Organisations Tackling Environmental Issues,* Allen and Unwin, Sydney.

Chisholm, A. H. 1997, "Policy Case of Australia", in *Agriculture, Pesticides and the Environment: Policy Options,* OECD, Paris.

Corbyn, L. 1996, "Pollution reduction strategies in the Hawkesbury Nepean Catchment", in *Proceedings of the 1994 Fenner Conference on the Environment, Sustainability: Principles to Practice*, Department of Environment, Canberra.

Crabb, P. 1997, *Impacts Of Anthropogenic Activities, Water Use and Consumption of Water Resources and Flooding,* Australia: State of the Environment Technical Paper Series (Inland Waters), Department of the Environment, Canberra.

Cullen P. and Bowmer, K. 1995, “Agriculture, Water and Blue Green Algal Blooms”, in *Sustaining the Agricultural Resource Base*, Office of the Chief Scientist, Department of the Prime Minister and Cabinet, Canberra.

Dixon, P.B., Parmenter, B.R., Sutton, J.M. and Vincent, D.P. 1982, *ORANI: A Multisectoral Model of the Australian Economy*, North-Holland, Amsterdam.

DFAT. (Department of Foreign Affairs and Trade) 1999, *Exports of Primary and Manufactured Products, Australia*, Trade Analysis Branch, Department of Foreign Affairs and Trade, Canberra.

DLWC (Department of Land and Water Conservation) 2000, “NSW Water Conservation Strategy”, NSW Department of Land and Water Conservation, Sydney.

Gunasekera, D. 1997, *Role of Economic Instruments in Managing the Environment,* Invited paper, Industry Economics Conference, Panel 3, Environmental Regulation, Melbourne, Industry Commission.

Jones, D. 1997, *Environmental Incentives: Australian Experience With Economic Instruments for Environmental Management,*. Environmental Economics Research Paper No. 5, Environment Australia, Canberra.

MDBC (Murray Darling Basin Commission) 1998, *Murray-Darling Basin Cap on Diversions Water Year 1997/98 Striking the Balance*, MDBC, Canberra.

MDBC 2001, “Basin Salinity Management Strategy 2001-2015”, MDBC, Canberra.

SEAC (State of the Environment Advisory Council) 1996, *Australia: State of the Environment*, An Independent report to the Commonwealth Minister for the Environment, Department of the Environment, Sport and Territories, (CSIRO Publishing), Melbourne.

Smith, D. I. 1998, *Water in Australia: Resources and Management*. Oxford University Press Australia, Melbourne.

Stringer, R. and Anderson, K. 2001 (forthcoming), “Australia”, in Brouwer, F. and Ervin, D. (eds.), *Public concerns, environmental standards and agricultural trade,* CABI Publishing, Wallingford:.

Young, M., Hatton, D., MacDonald, D., Stringer R. and Bjornland, H. 2000, “Interstate water trading in the MDB”, CSIRO, Adelaide.

Wittwer, G. 2000, *The Australian wine industry during a period of boom and tax changes*, unpublished Ph.D. dissertation, The University of Adelaide.

Table 1 Water use in Australia and its wine export competitors

	Per Capita Availability	Per Capita Use	Agriculture's Share	Irrigated Area
	m^3	m^3	%	(000) Ha
Chile	61,007	1629	84%	1,800
Australia	18,638	839	70%	2,057
Argentina	9,721	822	75%	1,561
US	8,838	1844	40%	21,400
France	3,047	704	12%	2,000
Spain	2,821	897	68%	3,640
Italy	2,080	840	53%	2,698
South Africa	1,110	391	72%	1,350

Sources: World Resources Institute 2000; FAOSTAT 2001.

Table 2: Area of crops and pastures irrigated in Australia, 1999

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australia
	Thousands of hectares						
Annual pasture	199	267	28	18	12	10	534
Perennial pasture	115	251	21	41	5	19	452
Rice	148	0	0	0	0	0	148
Other cereals	163	17	30	5	1	2	219
Cotton	256	0	117	0	1	0	375
Sugar cane	0	0	153	0	3	0	156
Vegetables	16	21	26	11	8	15	97
Fruit (incl. Nuts)	23	22	23	15	6	3	94
Grapevines	25	32	1	45	5	0	108
All other crops	29	9	20	7	2	9	77
Total	**974**	**619**	**417.4**	**138**	**42**	**58**	**2,251**

Source: ABS Cat. 7113.0.

Table 3: Australia net water use by sector, 1997

	ML	SHARE
Agriculture	15,502,973	69.9%
Services to agriculture	18,815	0.1%
Mining	570,217	2.6%
Manufacturing	727,737	3.3%
Electricity/gas	1,307,834	5.9%
Sewerage/drainage services	1,706,645	7.7%
Other	522,513	2.4%
Household	1,828,999	8.2%
Total	22,185,733	100.0 %

Source: ABS Cat. 4610.0.

Table 4: Australia irrigated water use, 1997

	Gross Value $M	Net Water Use ML	Share of Water Use	Area Ha	Share of Area	Water Applied ML/Ha
Livestock, Pasture, Other	2,540	8,795,428	56.7%	1,174,687	57.1%	7.49
Pasture				934,000	45.4%	
Cereals				184,000	8.9%	
Others				56,687	2.8%	
Vegetables	1,119	634,913	4.1%	88,782	4.3%	7.15
Sugar	517	1,236,250	8.0%	173,224	8.4%	7.14
Fruit	1,027	703,878	4.5%	82,316	4.0%	8.55
Grapes	613	648,574	4.2%	70,248	3.4%	9.23
Cotton	1,128	1,840,624	11.9%	314,957	15.3%	5.84
Rice	310	1,643,306	10.6%	152,367	7.4%	10.79
Total	7,254	15,502,973	100.0%	2,056,581	100.0%	7.54

Source: ABS Cat. 4610.0.

Table 5: Irrigation by Australian state, 1997

STATE	**Water use ML**	**Proportion of total water use %**	**Area Ha**	**Proportion of area %**	**Average water use ML/Ha**	**TONNES**	**T/ML**
NSW	242,288	37.4%	15,194	22%	15.95	209,901	0.87
VIC	217,888	33.6%	20,800	30%	10.48	329,687	1.51
QLD	4,062	0.6%	800	1%	5.08	4,530	1.12
SA	171,836	26.5%	30,432	44%	5.65	374,589	2.18
WA	11,113	1.7%	2,654	4%	4.19	21,796	1.96
TOTAL	647,187	100%	70,364	100%	9.19	943,113	1.45

Source: ABS Cat. 4610.0; ABS Cat. 7113.0.

Table 6: Water pricing reforms

Percentage change from base case unless indicated otherwise

	National	SA	ROA	
Aggregate consumption[a]	$29m	$39m	-$10m	
Salinity externality[b]	-$24m	$4m	-$28m	
		($3m)	($11m)	
Industry outcomes	**Output SA**	**Producer price SA**	**Output ROA**	**Producer price ROA**
Broadacre agriculture	0.09	0.00	-0.16	-0.03
Irrigated Pasture	0.99	-0.52	-0.66	-0.14
Irrigated Pasture VIC	..	..	-0.65	-0.14
Irrigated Pasture NSW	..	..	-0.99	12.65
Cotton	..	..	-0.37	2.09
Rice	..	..	-1.13	7.08
Other agriculture	0.19	0.00	-0.03	-0.02
Grapes	1.21	-0.67	-0.62	-0.12
Grapes NSW	..	..	-0.39	0.63

a The Commonwealth budget balance is exogenous.
b The standard deviation arising from varying the transformation parameter between outputs and salinity from 2.0±1.75 is in parentheses.

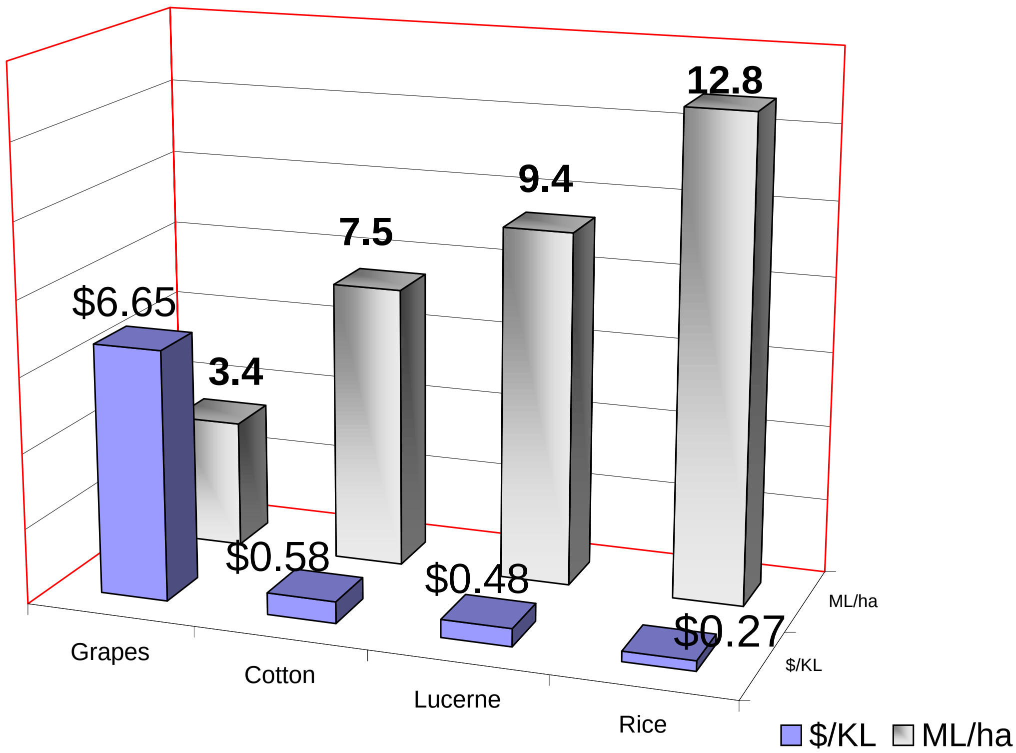
Table 7: Taxing the salinity damage of each irrigation activity

Percentage change from base case unless indicated otherwise

	National	SA	ROA	
Aggregate consumption[a]	-$95m	$30m	-$125m	
Salinity externality[b]	-$222m	$0m	-$222m	
		($10m)	($72m)	
Industry outcomes	**Output SA**	**Producer price SA**	**Output ROA**	**Producer price ROA**
Broadacre agriculture	0.18	-0.04	-1.27	-0.14
Irrigated Pasture	-3.27	6.95	-4.43	6.55
Irrigated Pasture VIC	..	..	-5.07	12.05
Irrigated Pasture NSW	..	..	-5.57	34.91
Cotton	..	..	-5.68	39.91
Rice	..	..	-5.69	40.04
Other agriculture	-0.80	0.03	-0.25	-0.15
Grapes	-3.04	7.53	-2.36	6.63
Grapes NSW	..	..	-3.27	6.95

a The Commonwealth budget surplus increases by $755m, with these funds used for salinity repair.
b The standard deviation arising from varying the transformation parameter between outputs and salinity from 2.0±1.75 is in parentheses.

Figure 1: Output per unit of water usage and water per hectare



Source: DLWC 2000.