Australian Government
Productivity Commission

Irrigation externalities: pricing and charges

Staff Working Paper

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The views expressed in this paper are those of the staff involved and do not necessarily reflect those of the Productivity Commission

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Foreword

This Staff Working Paper presents the results of research undertaken in the Productivity Commission's Environment and Resource Economics Branch during 2005. It is part of a larger suite of water policy research conducted by the Commission, including modelling of regional economic impacts of changes in water trade within the southern Murray–Darling Basin.

In December 2005, the Productivity Commission was asked by the Australian Government to undertake a major research study to assist implementation of the National Water Initiative. *'Rural Water Use and the Environment: the Role of Market Mechanisms'* will focus on water use efficiency and the feasibility of market mechanisms to address water-related environmental externalities (see www.pc.gov.au).

The Productivity Commission is releasing this Staff Working Paper as a complement to the new commissioned research study, to help inform public input into the ongoing investigation. The paper discusses the nature and causes of environmental change related to rural water use, and provides a taxonomy of the many diverse types. It also examines the possible role of a charge imposed by rural water utilities in managing externalities that may emerge.

Any feedback on this research will be considered in the context of the commissioned research study. However, the Staff Working Paper should not be seen as necessarily foreshadowing or circumscribing the Productivity Commission's views in the commissioned study.

Gary Banks
Chairman

March 2006

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Abbreviations and explanations

Abbreviations

ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
COAG	Council of Australian Governments
EC	electrical conductivity (a measure of salinity)
NCC	National Competition Council
NCP	National Competition Policy
PC	Productivity Commission
Water CEOs Group	Water Chief Executive Officers Group

Explanations

Billion	The convention used for a billion is a thousand million (10^9).
Gigalitre	One billion (10^9) litres.
Megalitre	One million (10^6) litres.

OVERVIEW

Key points

- Externalities associated with irrigation water supply and use are complex and the links between these sources of environmental change and their effects are not always well understood or measured.
- Many factors influence the extent to which a charge or tax on water use would actually change water use, including the volume of water available to irrigators, the extent to which trade can occur, the size of the tax, the price responsiveness for irrigation water, and the existing mechanisms to address externalities.
  - Where there is water trade and where restrictions on water allocations result in scarcity rents, a charge will only reduce water use (and consequent environmental costs) if it exceeds the scarcity rents. If water use does not change, there will be no short run improvement in economic efficiency from such a charge, although it might encourage long run efficiency improvements.
  - Scarcity rents will vary within and between irrigation seasons, as well as between irrigation districts.
- When assessing new policies to manage environmental externalities, care should be taken to define adequately the externality, and not simply identify instances of environmental change. Governments should carefully consider the potential benefits and costs in assessing such new policies.
- An externality tax can make the costs of negative externalities transparent and provide incentives to some relevant economic agents. A tax equal to the marginal external costs at each level of output can improve efficiency and in the longer term may provide an incentive to undertake abatement activities.
- A tax on water use may increase economic efficiency where external costs are related only to the level of water use. But such a tax is an unsuitable instrument if the government's policy objective is to reduce environmental damage to a pre-determined level or to raise a target level of revenue to address the externalities.
- Challenges in considering and implementing an externality tax include whether such a tax is appropriate for a particular externality, variations in efficiency benefits, interaction with other externalities, difficulties in determining the rate, use of the revenue and legal feasibility.

Overview

Key elements of the Council of Australian Government's 1994 strategic framework for water reform were consumption based pricing and full cost recovery. In 1998, to assist implementation of the water reforms, the former Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) endorsed guidelines for water pricing, including that water businesses should recover, among other costs, the costs of managing externalities. But there is confusion on the meaning of 'externalities', with some agencies and policy documents (including the National Water Initiative) appearing to adopt a cost recovery definition (recovering the environmental and natural resource management costs incurred by water businesses). Others (such as the High Level Steering Group on Water) use the economic definition of externalities (those side effects or spillovers of an activity that are not taken into account in an individual's or business' decision and that affect another party's wellbeing).

This Productivity Commission Staff Working Paper examines the extent to which charges imposed by irrigation water utilities can address externalities from irrigation water supply and use. It also develops a framework to identify and characterise changes in environmental conditions from the supply and use of irrigation water that may lead to environmental externalities.

Irrigation water use in Australia

Irrigated agriculture represents about 28 per cent of the gross value of agricultural production in Australia. Irrigation water is used to supplement rainfall in agricultural production systems. Agriculture accounts for about 67 per cent of all extracted water used in Australia, with most of the water used by Australian agriculture in New South Wales (44 per cent in 2000-01), Victoria (22 per cent) and Queensland (21 per cent).

Water utilities charge irrigators for the water allocated and/or delivered to farms. In addition to purchasing water from utilities, irrigators can trade entitlements (irrigators' access rights to a specific quantity of water each irrigation season, sometimes referred to as 'permanent trade') and seasonal allocations (the proportion of water entitlements allocated by water utilities during an irrigation season, sometimes referred to as 'temporary trade'). A variety of constraints limit the extent of the trade — in general, trade is less constrained within irrigation districts than between districts, and trade in seasonal allocations is less constrained than trade in entitlements. Differences can exist between utility charges and the traded price of irrigation water, representing scarcity rents accruing to some irrigators. These rents can be large, but vary over time and between regions.

Distinguishing environmental change from externalities

Many different environmental changes are associated with the supply and use of irrigation water, such as changes to hydrological conditions, habitat, water quality and ecological conditions. These changes can occur at each stage in the irrigation water supply and use chain covering harvesting, extraction, storage, diversion, delivery and use.

Often these environmental changes are associated with externalities (defined in economic terms). However, the occurrence of environmental change does not necessarily mean an environmental externality exists. An economic externality requires both the environmental change and a human reaction to that change. Thus, if there is environmental change that the community does not value (either positively or negatively), then an economic externality does not exist.

Not all externalities require public policy responses, whether by way of general legislation, regulation, pricing rules or case-by-case responses. The criterion is: 'would the expected benefits of action to reduce the externality exceed the expected costs of that action?' (where the benefits and costs are summed up across all affected individuals and communities). In general, it is unlikely that a complete elimination of an externality — reducing the spillover to zero — would satisfy this test.

The framework developed in this paper for analysing the characteristics of externalities incorporates three salient elements of an externality: its source(s), how it is transmitted and its effects (table 1). The characteristics of an externality affect the likelihood of private sector solutions being successfully undertaken, and influence the effectiveness of policy instruments.

Possible water supply externalities include alterations to river flows, cold water releases from dams and obstructions to fish passage. Possible water use externalities include waterlogging, land salinisation and downstream salinity. Many of the externalities associated with irrigation water supply and use are complex and the links between sources and effects are not well understood. At times, it is difficult to identify, observe and measure effects from individual sources, and resulting changes in environmental conditions.

Different parties can be positively and/or negatively affected by changes to environmental conditions caused by irrigation water supply and use in different ways. Environmental externalities can affect the productivity of industries that require water or land in their production processes. Domestic users can be affected through impacts on health or household infrastructure. Individuals (who may also be producers) can also be affected if they value water and land for recreational, indigenous, cultural and heritage reasons, or for the ecosystem services, species and habitat they provide.

Table 1 **Framework for analysing the characteristics of externalities**

Characteristic	*Source*	*Transmission*	*Effects*
Observability and measurement	Can the sources be identified? Can the activities of each source be observed? Do activities other than irrigation supply and use result in the externality?	Can the environmental changes caused by each source be observed and measured?	Can those who are affected be identified? Can the effects be observed and measured?
Spatial variation	Where are the source(s) located? Are they geographically diffuse? Do many sources contribute to the same effect?	Are the source(s) and effect(s) in a different location? Do the relationships between sources and effects change with location?	Where are the effects located? Are they geographically diffuse? Are many effects attributable to an individual source?
Temporal variation	To what extent do past activities have current (or future) effects? Are activities affected by the natural variability of ecosystems and ecosystem processes?	Are there time lags between source and effect? Are the lags at different temporal scales? Are relationships between sources and effects affected by natural variability?	Can effects be apportioned between past and ongoing activities? Are effects affected by natural variability?
Knowledge and uncertainty about processes	What is the nature of the relationships between sources and effects — for example, linear, increasing, decreasing, with threshold effects? Are the changes reversible or do they display hysteresis (whereby the nature of the relationship between two variables depends on whether the variables are increasing or decreasing)? Is there uncertainty about the relationship between (observable) activities and changes to environmental conditions? Is there uncertainty about the relation between changes to environmental conditions and effects?		

Addressing externalities

If private action fails to address an externality adequately, there may be a role for government intervention. However, the presence of an externality does not necessarily imply a case for government intervention. Addressing a market failure might not improve the allocation of resources, when account is taken of the costs of government action (such as the costs of policy development, administration, monitoring, enforcement and compliance). Governments should only intervene where the benefits from intervening are expected to outweigh the costs.

If there is a sufficient case for government intervention, a range of options is available — including using or creating markets, regulation and education and information. One approach is through the use of so called 'price instruments' such as taxes, charges or subsidies. An alternative approach is to use regulation to restrict the level of outputs or inputs ('quantity based instruments'). Price and quantity based instruments and the ability to trade can facilitate the market determining an efficient allocation of resources. There is no a priori reason to favour either price or quantity based instruments: the selection of instrument depends on a number of factors.

Important principles for assessing the use of policy instruments are appropriateness (is government intervention warranted; is the goal worth achieving?), effectiveness (does the policy achieve the stated objectives?), efficiency (does the policy achieve the highest net benefit of all alternative policies?) and equity (is the distribution of costs and benefits 'fair'). In designing and assessing policy instruments to manage environmental externalities associated with the irrigation industry, the aim should be to 'internalise' an appropriate level of external costs from changing environmental conditions. When assessing new policies to manage environmental externalities, care should be taken to define adequately the externality, and not simply identify instances of environmental change.

Effects of an externality charge or tax

An externality charge or tax can be used to ensure the costs of negative externalities are transparent and provide appropriate incentives to economic agents (similarly, a subsidy can ensure the benefits of positive externalities are included in private decision making). Such a charge (or corrective tax) on water use (that is, an addition to existing utility charges) has been proposed as one way to address environmental externalities from water harvest, storage, delivery and use.

An optimal (or properly calibrated) Pigouvian tax schedule (after the British economist, A.C. Pigou) would be equal to the marginal external cost at each level of the various associated activities (not only their current level). Introducing such a tax can improve efficiency (by equating the marginal private benefit with the marginal external cost of the activity) and provide the correct incentive to undertake abatement activities. However, there may be policy options superior to Pigouvian taxation schemes (that is, produce larger aggregate economic benefit).

An optimal Pigouvian tax schedule would signal the marginal social cost of water for all relevant levels of water use. Irrigators then decide how much water to use. The resultant environmental change is the optimal externality. There is no necessary connection between the tax revenue so raised, and the optimal level of public expenditure on abating the environmental change.

To devise the optimal Pigovian tax schedule, information is required about the marginal external damage caused at relevant levels of water use. If information is available only at one or a limited number of levels of water use, then governments could apply a simpler tax schedule (for example, a tax per unit of water use, regardless of volume). Alternatively, on some other basis, governments may set a target for the reduction in the environmental effect, to be achieved by the use of regulation, rather than taxation, or by some combination.

Issues in implementing an externality tax on water use

The extent to which a tax changes water use depends on many factors, including the size of the tax, the effect of the tax on the price of water, the price responsiveness of irrigation water use, the volume of water initially allocated to irrigators, the extent to which trade can occur, and existing mechanisms to address externalities.

A tax when there is no trade

When there is no trade, responses by irrigators are likely to be small or zero unless the charge is very high. If irrigators are significantly constrained by the size of their allocation (and so use their full allocation), a small charge is unlikely to change their water use. A green tea farmer, for example, could face a reduction in profit if using even marginally less water significantly reduces the quality of their crop. This irrigator is likely to continue to demand the same amount of water from utilities to meet the quality standards — despite the externality charge — except in very wet seasons. Charges that are high enough to influence water use may involve significant adjustment costs.

A tax when there is water trade

When there is water trade, and where restrictions on water allocations result in scarcity rents (such as in the southern Murray–Darling Basin), a Pigouvian tax on the use of irrigation water will ensure that the external costs of water use are transparent. But, just as in the previous case, an optimal tax would only change the quantity of water used (and therefore the level of environmental externalities) if the tax exceeds the scarcity rents. Further, if water use does not change, there will also be no short run improvement in economic efficiency from introducing the tax (although the tax itself is an efficient way of raising government revenue).

Nonetheless, efficiency might still improve in the longer term. Irrigators might undertake abatement activities where these cost less than the tax saved, and if they expect the level of tax in the future to adapt to the reduced negative externalities from the abatement activities.

Other issues in designing an externality tax

Challenges in deciding whether to implement an externality tax, and in designing such a tax, include (apart from the issue just discussed):

- whether such a tax is appropriate for a particular externality
- variation in efficiency benefits
- potential interaction with other externalities
- difficulties in determining the rate of such a tax
- use of the tax revenue
- legal feasibility.

A tax on water use may be an appropriate policy tool for some, but not all externalities. A tax used to signal the marginal social cost of the activity creating the externality is suited to externalities where the external costs are related to the level of the taxed activity (that is, those imposing marginal costs for each unit of output). Where the link between the activity causing the externality and the external costs is weak, the tax may fail to induce those undertaking the activity to change their behaviour, and might create further market distortions. Thus, a tax on water use can be suitable for addressing externalities of irrigation water supply and use, such as instream salinity. Other externalities, such as obstructions to fish migration, can create an externality with their existence, regardless of the level of water use; a volumetric tax on water use is not well suited to addressing such externalities. Therefore, understanding the features of environmental externalities is important when considering whether they are affected by changes in irrigation water use and consequently suited to a tax on water use.

The efficiency benefits from introducing a tax can also vary with circumstances. Existing policy responses to deal with externalities (such as quantity restrictions) might already have achieved some of the potential efficiency gains of a tax (thus reducing the benefits of introducing a tax). Nonetheless, short term efficiency benefits along with potential longer term efficiency benefits might still make it worthwhile in some circumstances to introduce a tax.

A tax on water use might also influence externalities other than those it was designed to address. At times, water losses from the conveyance of irrigation water, for example, may benefit local producers and the functioning of natural ecosystems. The use of an externality tax may lead to reduced irrigation and so reduce these positive effects. Further, the use of an externality tax may also lead to unintended behaviour, such as excess pumping of groundwater and the installation of farm dams to capture surface runoff before it enters river and groundwater systems. These responses could have a detrimental effect on river flows, the environment and in the longer term, production. The potential for unintended side-effects of policy is not unique to taxes.

Determining the optimal rate of a tax for irrigation externalities would be difficult. In Australia, there appear to be few studies that would provide policy makers with estimates of the likely marginal costs of externalities to set a tax. An ideal tax (a Pigouvian tax) would need differing rates across different locations and times, to reflect the varying costs of externalities over location and time. Such an approach would be costly to design and implement. Nonetheless, introducing a quasi-Pigouvian tax set below the optimum level will likely improve efficiency, with the marginal improvements in efficiency decreasing as the tax rate approaches the optimum level. Thus, one strategy might be to implement such a tax at an approximate, but conservative, level. In the future, as information improves on the likely marginal costs of externalities, the tax rate could be revised.

If a tax were imposed, a significant issue is how the collected revenue should be spent. Allocating such revenue to address environmental problems associated with the externality would require careful consideration. The revenue raised might be higher (or lower) than the optimal level of expenditure on remedying and/or preventing environmental damage. Nonetheless, using the revenue to address the externality may make such a tax more acceptable to the community.

The legal feasibility of an externality charge would require examination. An externality charge is a tax imposed on an input to production and hence it could be considered an excise duty. However, under Section 90 of the Australian

Constitution, excise duties cannot legally be imposed by the States and Territories — only the Australian Government may impose them. Further, under section 51(ii), taxes must not generally discriminate between States or parts of States. Any differentiation of an externality charge or tax would have to be clearly based on differences in environmental conditions that result in different environmental effects from the taxed activity.

1 Introduction

A key element of the 1994 Council of Australian Governments' (COAG) strategic framework for water reform was water pricing based on the principles of consumption based pricing and full cost recovery. In 1998, the former Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) provided guidance on water pricing, including that water businesses should recover the costs of managing externalities.

Between 1995 and 2004, the National Competition Council (NCC) was responsible for assessing State and Territory progress with water reform under the National Competition Policy (NCP). From 2005, the recently established National Water Commission will assess progress with the entire water reform program. This Productivity Commission staff working paper examines the extent to which charges imposed by irrigation water utilities can address externalities from irrigation water supply and use.

1.1 Irrigation water use in Australia

Irrigated agriculture represents about 28 per cent of the gross value of agricultural production in Australia. Approximately 2.5 million hectares of land were irrigated in 2001-02, a 22 per cent increase since 1996-97 (ABS 2004). Irrigation water is used to supplement rainfall in agricultural production systems.

Agriculture accounts for about 67 per cent of all water used in Australia (table 1.1). There is significant variation in the proportion of water consumed by agriculture across jurisdictions, ranging from about 40 per cent in Western Australia, to 79 per cent in South Australia. Most of the water used by Australian agriculture is used in New South Wales (44 per cent), Victoria (22 per cent) and Queensland (21 per cent).

The major agricultural water users include the livestock, pasture and grain industries (accounting for 33 per cent of water use in agriculture); the cotton and dairy farming industries (17 per cent each) and the rice industry (12 per cent). The sugar and horticultural (vegetables, fruit, nuts and grapes) industries are also significant users.

Table 1.1 **Total water use[a] for selected industries, 2000-01**

Gigalitres

	NSW–ACT	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*NT*	*Aust*
Livestock, pasture, grains and other agriculture	2 590	1 435	779	474	176	85	30	5 568
Dairy farming	401	1 685	288	320	65	76	–	2 834
Vegetables	96	131	103	65	111	49	1	556
Fruit	214	209	107	161	65	10	36	803
Grapes	174	238	6	284	23	1	3	729
Sugar	1	–	1 186	–	124	–	–	1 311
Cotton	1 921	–	985	–	3	–	–	2 908
Rice	1 924	27	–	–	–	–	–	1 951
Total for agriculture[b]	7 322	3 725	3 454	1 302	565	222	70	16 660
Total	9 425	7 140	4 711	1 647	1 409	417	160	24 909

a Total water use = mains water use + self-extracted water use + reuse water. **b** Columns may not add to total because of rounding. – Nil or rounded to zero.

Source: ABS 2004.

Irrigators can source irrigation water in a variety of ways, including:

- from on-farm diversion and storage of surface water flows
- from on-farm pumping and diversion of groundwater
- by diverting water from on-farm water courses
- via major storage, diversion and delivery infrastructure systems managed by public and private utilities (sometimes referred to as supplemented irrigation).

Most irrigation districts are concentrated in the eastern States of New South Wales, Victoria and Queensland, and draw water from Great Dividing Range catchments. Over 70 per cent of irrigation use occurs within the Murray–Darling Basin, with most supplemented irrigation located within the southern Murray–Darling Basin. In many cases, these irrigation districts could not sustain their current farming practices without irrigation.

Within each irrigation district, water utilities deliver water to irrigators predominantly via gravity feed delivery systems. During an irrigation season, the utilities usually charge irrigators for the water allocated and/or delivered to farms.

Utility charges are designed primarily to recover the operational, maintenance and some capital costs associated with water supply activities, including environmental management costs. In most districts, utilities charge irrigators a two-part tariff consisting of a fixed component (a charge based on the volume of an irrigator's water entitlement), and a variable component (a charge either on the volume of water allocated or the volume delivered during an irrigation season) (Appels, Douglas and Dwyer 2004). The average charge by utilities for irrigation water in 2001 was an estimated $23.51 per megalitre (ANCID 2002).

In some areas in Australia, irrigators can trade unused water entitlements (irrigators' access rights to a specific quantity of water each irrigation season, sometimes referred to as 'permanent trade') and seasonal allocations (the proportion of water entitlements allocated by water utilities during an irrigation season sometimes referred to as 'temporary trade'). In the southern Murray–Darling Basin, the market price of seasonal allocations often exceeds the utility charges (representing scarcity rents). The market price, rather than the utility charge, is the opportunity cost of water to the irrigator and the price on which production decisions are made (appendix A). Prices for seasonal allocations rose significantly during the recent drought, for example, and traded well above utility charges (Appels, Douglas and Dwyer 2004). At other times, utility charges may exceed the marginal value and traded price of water, for example, during flood periods. When trade in seasonal allocations occurs, the seller is responsible for fixed charges related to the traded entitlement. In some irrigation areas, water entitlements are to be unbundled into components, such as entitlements to access and delivery, that could potentially be traded separately.

Supplying and using water can have a wide range of effects on the environment through changes to the hydrology, water quality and ecological conditions (chapter 2). There are already many ways in which such effects are being addressed (box 1.1), and any new measure would need to take these into account.

1.2 Water reform in Australia

The 1994 COAG strategic framework for water reform encompassed economic, environmental and social objectives. Key elements of the strategic framework were to reform pricing based on the principles of consumption based pricing and full cost recovery; to reduce or eliminate cross-subsidies; and to make subsidies transparent. The framework also involved the clarification of water property rights, the allocation of water to the environment, the adoption of water trading arrangements, institutional reform and improved public consultation (NCC 1998).

In 1995, COAG brought the water reform program under the ambit of the NCP as part of a process to accelerate and broaden microeconomic reform. Between 1995 and 2004, the NCC was responsible for assessing State and Territory governments' progress with NCP reforms (including water). Following its assessment of jurisdictions' progress with NCP reforms, the NCC made recommendations to the Australian Government Treasurer on competition payments to States and Territories

(NCC 2004a). These payments are linked to, among other conditions, the implementation of the agreed water reforms (NCC 2001).

Box 1.1 **Current approaches for addressing environmental effects**

A variety of policies and instruments directly or indirectly influence the levels and distribution of environmental change caused by irrigation water supply and use at the local, district and interdistrict levels. These include voluntary responses, education and information, regulation and using and creating markets. Examples of current regulatory approaches include the following:

- Broad government environmental programs and initiatives, such as the National Action Plan for Salinity and Water Quality, the Natural Heritage Trust and The Living Murray, are funding vehicles for resource management objectives. They usually combine regulation with other approaches.
- Water reserved for environmental flows, either through the prescription of environmental flows or the allocation of water to the environment.
- Natural resource management plans may contain requirements for large capital works to mitigate the effects of irrigation salinity.
- Jurisdictions usually require utilities to undertake natural resource management activities as a condition of their operating requirements. In Victoria, for example, rural water authorities are required to meet riparian and instream environmental objectives as part of their bulk entitlement order.
- Applicants for water rights may be required to prepare farm-level plans for their property, to ensure best practice in irrigation and drainage management, water use efficiency, and the management of environmental effects.

There has been limited use of markets for managing environmental effects of irrigation. Such approaches can encourage individuals and/or businesses to undertake pollution control efforts that are both in their own interests and collectively meet broader policy goals (Stavins 2002). These instruments can be more efficient than prescriptive regulation because they allow producers to make their own benefit–cost tradeoffs in pursuing specific practices. Consequently, they may achieve desired regulatory outcomes in least cost ways. A lack of information or high costs associated with market creation and participation may outweigh these potential benefits, however. In other cases, such as when the environmental outcomes from market based instruments may be uncertain, or when environmental thresholds may be breached, the application of such instruments will be limited.

Voluntary approaches to address environmental effects of irrigation water supply and use include environmental management systems, codes of practice, and cooperative and partnership agreements. The Ricegrowers Association of Australia, for example, has a voluntary accreditation program that recognises irrigators for achieving a range of environmental management standards. Murray Irrigation undertakes environmental activities beyond those required under its operating licence, including a wetland watering trial, storm water channel construction, biodiversity education and water testing accreditation (Murray Irrigation 2002).

In June 2004, the Australian Government and the governments of New South Wales, Victoria, Queensland, South Australia, the ACT and the Northern Territory agreed to the National Water Initiative (COAG 2004). Tasmania became a signatory to the National Water Initiative in June 2005. As part of this initiative, these governments also agreed to establish the National Water Commission to advise COAG on national water issues and assist with implementing the water reform program, including undertaking the 2005 assessment of States' and Territories' implementation of NCP water reform commitments (NCC 2004b, pp. 1.3–1.5).

Guidance on water pricing and externalities

In 1998, ARMCANZ endorsed guidelines for water pricing, including that water businesses should recover the costs of externalities:

> 5. To be viable, a water business should recover, at least, the operational, maintenance and administrative costs, externalities, taxes or [tax equivalent regimes] (not including income tax), the interest cost on debt, dividends (if any) and make provision for future asset refurbishment/replacement ...
>
> 7. In determining prices, transparency is required in the treatment of community service obligations, contributed assets, the opening value of assets, externalities including resource management costs, and tax equivalent regimes. (NCC 1998, pp. 112–13)

ARMCANZ defined 'externalities' in sections 5 and 7 of the guidelines as 'the environmental and natural resource management costs attributable to and incurred by the water business' (NCC 1998, p. 113). The guidelines have in-built flexibility by providing a band of prices through which water businesses could achieve full cost recovery. Full cost water pricing was to be set within upper and lower bounds, with the upper bounds set to avoid monopoly rents and the lower bound set to ensure viability. Both bounds were to include costs associated with externalities.

The ARMCANZ definition of externalities contrasts with economic definitions, which view externalities as the side effects or spillovers of an activity that are not taken into account in an individual's or business' decision to undertake an activity and that affect another party's wellbeing (section 1.3 discusses this issue further).

In 2000, a High Level Steering Group on Water (comprised of representatives of the agriculture and environment agencies of the Australian Government and State governments) developed *Draft guidelines for managing externalities*. The steering group proposed a nine step process for managing water externalities and defined 'externalities' as 'the indirect or accidental consequences of actions associated with economic activity' (High Level Steering Group on Water 2000, p. 6). This definition, similar to the economic definition provided above, differs from the cost recovery perspective of the ARMCANZ endorsed guidelines.

The steering group suggested addressing externalities by using a portfolio of tools, including property rights, charging, grants and rebates, and standards. It also noted that pricing will not always be sufficiently robust, when employed exclusively, to carry all the information necessary to manage externality costs effectively (High Level Steering Group on Water 2000).

Perhaps trying to bridge the gap between the definitions of ARMCANZ and the guidelines of the High Level Steering Group on Water, the NCC advised:

> The COAG pricing guidelines require externalities to be incorporated into prices. The Council recognises that this is a complex and difficult area, particularly in the urban sector. The Council views the first step as ensuring prices reflect an appropriate proportion of the costs of mitigating environmental problems of water use. The more advanced stage is a holistic approach to dealing with externalities, where pricing is only one component. (NCC 2002, p. 2.60)

In 2003, the NCC suggested that 'the minimum requirement is for the cost of the environmental requirements on water businesses to be passed on to water users' (NCC 2003a, p. 7). It also encouraged:

> ... all governments to take a broader view of environmental costs when considering pricing water supplied outside of irrigation districts than the minimum COAG requirement. Taking a broader view, prices should incorporate two aspects of the cost of water: the cost of delivering water; *and* the cost of managing the environmental consequences of *using* water where it is appropriate for these costs to be paid by water users. (NCC 2003a, p. 7) [emphasis added]

The NCC observed, however:

> Because of the uncertainty of environmental impacts and the range of tools that might be used to address environmental questions, the Council does not see the water pricing guidelines as requiring a particular level of externality charge to be applied to meet full cost recovery guidelines. Rather, the obligation is that prices faced by water users transparently reflect externalities that are attributable to and incurred by water service providers. (NCC 2003b, p. 14)

It is not clear from the above statements what definition of externalities the NCC adopted. Further, the various NCC statements appear to assume equality between delivery charges and water prices, but these can differ due to scarcity rents (chapter 4).

Progress with COAG water reforms regarding externalities

In 2002, a cross-jurisdictional departmental Water Chief Executive Officers Group (Water CEOs Group) reported to COAG on progress with water reforms. It concluded:

> … while good progress has been made in ensuring that prices fully recover the costs of built infrastructure, there has been no resolution to the debate about the extent to which prices should recover the cost of externalities, like damage to the natural infrastructure of the environment. (Water CEOs Group 2002, p. 4)

In August 2003, COAG (2003, p. 1) agreed on the need to refresh the 1994 water reform agenda 'to increase the productivity and efficiency of water use, sustain rural and urban communities, and to ensure the health of river and groundwater systems'. COAG stated that a key objective of the National Water Initiative would be 'the establishment of best practice water pricing'; and that this would involve 'the principles of user pays and full cost recovery, and include where appropriate, the cost of delivery, planning, and environmental impact' (COAG 2003, p. 3).

Under clause 73 of the National Water Initiative, COAG agreed to:

> (i) continue to manage environmental externalities through a range of regulatory measures (such as through setting extraction limits in water management plans and by specifying the conditions for the use of water in water use licences);
>
> (ii) continue to examine the feasibility of using market based mechanisms such as pricing to account for positive and negative environmental externalities associated with water use; and
>
> (iii) implement pricing that includes externalities where found to be feasible. (COAG 2004, clause 73)

The language of the National Water Initiative document may contribute to confusion of the objective with respect to externalities by also referring to recovering the costs of environmental externalities (for example, clause 65).

1.3 What are economic externalities?

Economics defines an externality as the side effects or spillovers of an activity that are not taken into account in an individual's or business' decision to undertake the activity and that affect another party's wellbeing. An externality may be positive or negative in its effect. A positive externality occurs when one party generates external benefits to another, for which the first party receives no payment or compensation. In other words, it raises the production or utility of the externally affected party. An example of a positive externality is the benefit that neighbouring farmers may derive from a beekeeper whose routine activities supply pollination services without charge. A negative externality generates external costs (box 1.2).

Box 1.2 Example of a negative externality

Consider an upstream industry, such as a dairy farm, that discharges waste into a river as a by product of production. This waste may cause harm to a downstream user of that water, such as a freshwater trout farm. Without the ability to influence the dairy farm to reduce waste output, the trout farm must either shut down or introduce water filters to clean the water before its use. If the dairy farm operates without accounting for the negative effects on the industry downstream, it is said to be generating an external cost, or a negative externality. Conversely, if the trout farm chooses to locate downstream from the dairy farm without accounting for possible negative effects of the discharged waste, this decision also generates an external cost.

There is an important distinction between the physical presence of a pollutant (such as waste discharging into a river) and a negative externality which can arise from the pollution. The mere presence of pollution does not necessarily mean there is an externality: the economic definition of an externality requires both (1) the pollution and (2) a human reaction (reduced wellbeing) to that physical effect (Pearce and Turner 1990, p. 61). Further, the economically optimal level of pollution is unlikely to be zero.

Some activities that cause externalities may be modifiable in such a way that the externally affected party can be made better off without the affecting party being made worse off (a 'pareto-relevant' externality) — that is, there is a possibility of gain from trade between the two parties. The divergence between the net social benefits and the net private benefits associated with a negative externality can (but does not necessarily), lead to an inefficient allocation of resources (chapter 3). Positive externalities have the opposite effects to negative externalities. Given that markets for one good are related to markets for other goods, the ultimate effects may be widespread.

1.4 Outline of the report

Chapter 2 presents a framework to identify and characterise key environmental changes that can arise from the supply and use of irrigation water. Potential physical and economic effects of water supply and use need to be identified and understood to assess potential policy instruments to manage water externalities.

Chapter 3 details the economic effects of externalities. It discusses how and when private action is likely to address externalities, and the role (if any) of government intervention. Chapter 4 discusses issues involved in implementing a corrective (or Pigouvian) tax on irrigation water use.

2 Environmental change and externalities from irrigation water supply and use

This chapter discusses a variety of environmental changes and externalities that may arise from the supply and use of irrigation water. Environmental changes will not always involve externalities. Environmental changes and externalities that may result from the actions of rural water utilities and irrigators are identified (section 2.1). Then, a framework for analysing the characteristics of externalities is described (section 2.2). The framework is then applied to selected externalities from irrigation water supply and use (sections 2.3 and 2.4).

2.1 Identifying environmental change and externalities

Environmental change can occur at each stage in the irrigation water supply and use chain:

- harvesting — activities within a catchment that influence the volume and quality of water available from natural sources for supply by rural water utilities — for example, the construction of farm dams and land clearing which may affect overland runoff to streams and groundwater
- extraction — activities undertaken to extract groundwater for irrigation
- storage — the construction, operation and maintenance of reservoirs, including releases of water from outlets to natural and to man-made carriers
- diversion — the construction, operation and maintenance of weirs, locks, levees and other regulators that are used to control the flow of water in natural and to man made carriers
- delivery — the construction, operation and maintenance of infrastructure (including open channels, pipes, pumps and meters) that is used to deliver water from reservoirs and weir pools to irrigated properties (between a utility's bulk water meter and on-farm meters)
- use — the application of water to irrigate crops and pasture via irrigation technologies, drainage and re-use techniques.

Some environmental changes may arise from a combination of activities conducted by different agents in different stages of this chain. Blue green algal blooms, for example, may be caused by the combination of increased nutrient loads to rivers (possibly a result of fertiliser application by irrigators) and decreased river flows (possibly a result of actions by water utilities and irrigators). Other activities, such as dryland farming that contributes sediment and nutrient loads to river systems, may also cause environmental change.

Distinguishing environmental change from externalities

Environmental change will not always result in economic externalities — the side effects or spillovers of an activity that are not taken into account in an individual's or business' decision to undertake the activity and that affect another party's wellbeing. An economic externality requires both the environmental change and a human reaction to that change (chapter 1). Thus, if there is environmental change but the community does not value it (either positively or negatively), then an economic externality does not exist. For example, there is no externality if a farmer's water use increases salinity, but only on his property, which does not affect another party's wellbeing, economic or otherwise, other than fully through the market price of the affected land.

2.2 Framework for analysing the characteristics of externalities

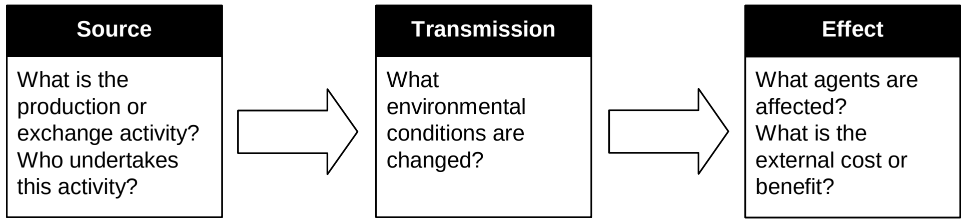
Three salient elements of an externality associated with environmental change are the source(s) of environmental change, how it is transmitted and its effects (figure 2.1). Identifying externalities involves describing (1) how production or exchange activities may cause changes to environmental conditions, for example, and (2) the effects on other agents. Using these elements, the framework for analysing the characteristics of externalities is presented in table 2.1.

Understanding the characteristics of externalities can assist in assessing whether they are affected by changes in irrigation water supply and use. Challenges include:

- difficulty in observing and monitoring the environmental changes caused by each source, which may vary significantly (in direction and magnitude) across different locations
- the degree of spatial and temporal variation with environmental change
- whether several sources contribute to the same effect, or a single source results in several effects, and identifying those causing an environmental change

- the degree of knowledge and uncertainty about the relationships between supply or use activities, and the resultant changes to environmental conditions.

Figure 2.1 **Key elements of an externality associated with environmental change**



Externalities can arise from point and non-point sources. Point sources arise from specific locations (such as a pipe or outfall), whereas non-point sources arise in a more indirect and diffuse way (such as contamination from fertiliser used in agricultural activity) (Tietenberg 1992, p. 479). The sources (point and non-point) and effects of irrigation water externalities are likely to vary significantly over location and time. Further, the relationships between activities, changes to environmental conditions, and effects can be uncertain or variable. This can be particularly true for non-point source externalities (see, for example, Dosi and Moretto 1994; Ribaudo, Horan and Smith 1999; Tomasi, Segerson and Braden 1994).

Describing the source of irrigation water externalities involves identifying the:

- agents associated with the supply and use chain (rural water utilities or irrigators)
- activities conducted by these agents that could lead to positive or negative effects on other parties (table 2.2).

Sources of externalities

In supplemented irrigation districts, rural water utilities are responsible for the provision of irrigation water — that is, the storage, diversion and delivery of water to irrigators. Their activities include constructing, operating and maintaining supply infrastructure (including, in some districts, pumping groundwater). The infrastructure includes the system of headworks, dams and weirs on natural watercourses, as well as the channels, pumps, pipes and meters used in distributing water to irrigators. The activities of rural water utilities depend, to varying extents, on the activities of irrigators and the design of the supply system — for example.

The timing and volume of irrigation water demand influences the release of water from dams.

Table 2.1 **Framework for analysing the characteristics of externalities**

Characteristic	*Source*	*Transmission*	*Effects*
Observability and measurement	Can the sources be identified? Can the activities of each source be observed? Do activities other than irrigation supply and use result in the environmental change?	Can the environmental changes caused by each source be observed and measured?	Can those who are affected be identified? Can the effects be observed and measured?
Spatial variation	Where are the source(s) located? Are they geographically diffuse? Do many sources contribute to the same effect?	Are the source(s) and effect(s) in a different location? Do the relationships between sources and effects change with location?	Where are the effects located? Are they geographically diffuse? Are many effects attributable to an individual source?
Temporal variation	To what extent do past activities have current (or future) effects? Are activities affected by the natural variability of ecosystems and ecosystem processes?	Are there time lags between source and effect? Are the lags at different temporal scales? Are relationships between sources and effects affected by natural variability?	Can effects be apportioned between past and ongoing activities? Are effects influenced by natural variability?
Knowledge and uncertainty about processes	What is the nature of the relationships between sources and effects — for example, linear, increasing, decreasing, with threshold effects? Are the changes reversible or do they display hysteresis (whereby the nature of the relationship between two variables depends on whether the variables are increasing or decreasing)? Is there uncertainty about the relationship between (observable) activities and changes to environmental conditions? Is there uncertainty about the relation between changes to environmental conditions and effects?		

It may not always be possible to apportion causes of environmental change among different point and non-point sources, given the complex interactions of various activities and the environment. Non-point source environmental effects are complicated if it is not possible to identify the responsible agents, and/or where agents are not in close proximity. These factors lessen the likelihood of successful actions being taken to address these externalities. The development of new technology, however, may increase the ability to monitor and manage non-point source effects — for example, technology to monitor groundwater salinity flows.

Table 2.2 **Sources of irrigation water externalities**

Supply and use chain	*Agent*	*Activities*
Supply (harvesting, extraction, storage, diversion and delivery)	Rural water utilities	Constructing, maintaining and operating supply infrastructure, including dams, weirs, channels, pipes and pumps
Use	Irrigators	Applying water to crops and pasture, which involves or may involve irrigation scheduling, a choice of irrigation technology, a choice of cropping options, and on-farm water storage, re-use and drainage[a]

[a] Rural water utilities also may provide drainage services.

Transmission of externalities

An externality may be transmitted through changes to environmental conditions. Irrigation water supply and use activities may cause changes to hydrological, water quality and ecological conditions (table 2.3).

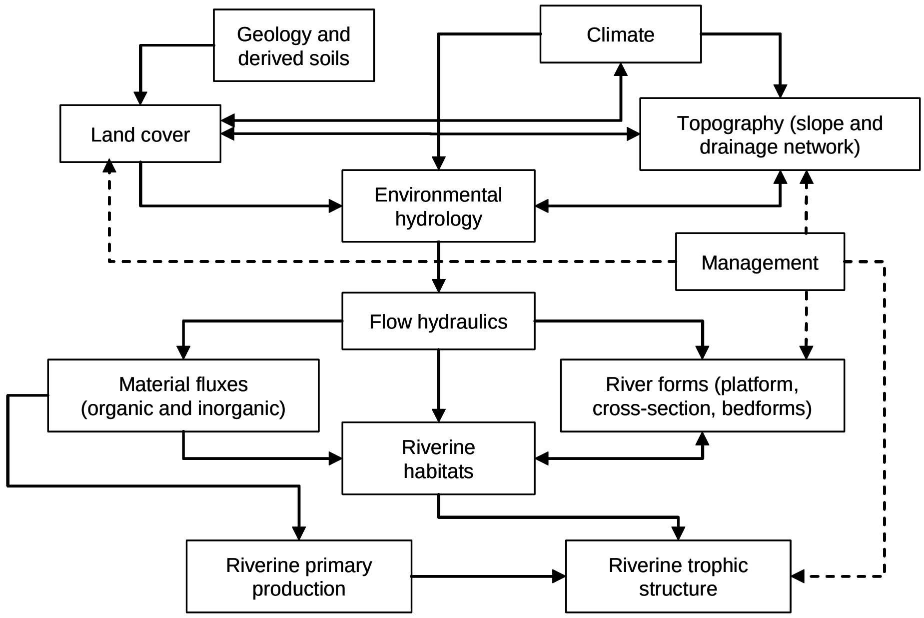
Table 2.3 **Transmission of irrigation water externalities**

Environmental condition	*Examples of indicators of change*
Hydrology	Flow volume and depth, flow variability, seasonality, flooding frequency and surface water area
Water quality	Salinity, biological oxygen demand, pH level (measure of acidity or alkalinity), temperature, sediment concentration, turbidity, and nutrient and chemical concentration
Ecology	Species numbers, composition, species diversity, changes in physical habitat (including channel form, meanders and sedimentation and habitat availability) and ecosystem processes (including the reproduction of flora and fauna)

Hydrological and water quality changes can occur in both surface water (including estuarine regions) and groundwater. Changes to ecological conditions may affect species numbers, composition and diversity. The number and abundance of native fish species may change, for example, or the composition of floodplain vegetation. Changes in land use and hydrology can also alter the river habitat, perhaps changing channel form, sediment size and particle distribution, and reducing habitat diversity by filling deep holes with sediment.

The attributes of rivers, floodplains, groundwater and estuaries — including hydrological, water quality and ecological conditions — are linked by physical processes. Changes in a flow regime, for example, can cause changes in material transport and river form, which can lead to ecological changes. Links between the key attributes of a river system are summarised in figure 2.2.

Figure 2.2 **Links between the attributes of a river system**



Source: Young 2001.

Effects of externalities

Many different parties can potentially be affected, and in different ways, by environmental changes caused by irrigation water supply and use. These effects can be positive or negative. Externalities can affect the productivity of industries that require water or land in their production processes (including agriculture, fishery, forestry, mining and manufacturing). Domestic users can be affected by impacts on their health or household infrastructure. Individuals (who may also be producers) can also be affected if they value water and land for recreational, indigenous, cultural and heritage reasons, or for the ecosystem services, biodiversity and habitat they provide (table 2.4).

The nature of potential environmental effects depends on many factors, including the volume, timing and location of irrigation. The activities influencing these characteristics include irrigation scheduling and on-farm and off-farm water storages, drainage and re-use. In many areas, water utilities provide surface and sub-surface drainage services to landholders.

Table 2.4 **Effects of irrigation water externalities**

Who is affected[a]	*Potential effects*
Agricultural producers	Productivity, input costs
Other industries	Productivity[b], input costs
Domestic consumers	Health, household infrastructure
Individuals	Recreation and amenity, culture and heritage (including indigenous values), regional infrastructure (including roads, pipes, cables, railways), ecosystem services, biodiversity, habitat

a Some externalities may affect individuals who belong to more than one category. Rising saline groundwater, for example, may reduce crop productivity and result in reduced biodiversity and habitat loss of wetlands. An agricultural producer may be affected by both the reduction in crop productivity and the decline in wetland health, if the producer values wetlands. **b** For industries such as tourism and recreational fishing, an externality may be defined as an effect on consumer expenditure (rather than production).

2.3 Applying the framework to irrigation water supply externalities

This section identifies and characterises some of the main irrigation water supply externalities associated with storage, diversion and delivery of water. Storage and diversion externalities are associated with constructing, maintaining and operating storage and diversion infrastructure. 'Storage' involves constructing and operating reservoirs. Water is released from a reservoir storage through controls on the outlet tower, which is usually built immediately upstream of a dam wall. 'Diversion structures' include weirs, locks and regulators that are used to control the flow of water. Weirs raise the water level along watercourses (creating weir pools) so water can be diverted and allowed to flow, under gravity, along networks of channels and pipes to users (Goulburn-Murray Water 2001). Storage and diversion activities can result in externalities by modifying the flow patterns in watercourses, which have ecological and water quality effects (see, for example, Thoms et al. 2000). The sources, transmission processes and effects of some of the main externalities associated with water storage and diversion are summarised in table 2.5. An individual activity may have many types of effects, and any individual effect may be the result of multiple activities.

Water is delivered to irrigators through networks of open channels (lined or unlined), pipes, pumps and meters operated by rural water utilities. Table 2.6 presents examples of possible delivery externalities, including channel outfalls, leakage and seepage.

Table 2.5 **Examples of possible water storage and diversion externalities**

Source	*Transmission*	*Effects*
(a) What is the activity? *(b) Who undertakes this activity?*	*What changes to environmental conditions can occur?*	*Who can be affected? Are there external costs or benefits?*
1. Creation of dam waterbodies (a) Construction of reservoir and maintenance of water storage levels (b) Water utility (or other organisations) responsible for construction and operation of reservoir	Hydrology — creates a water-body; reduces flow Water quality — constant, stratified water levels have the risk of algal blooms Habitat — creates non-flowing lakes upstream; reduces the amount of submerged habitat downstream Ecology — obstructs fish migration pathways; affects species and communities by changing the hydrology (for example, the flow regime); results in habitat loss	Landholders and businesses — benefits from reduction of flood effects Recreational users — benefits from increased recreational opportunities Tourism industry — benefits from increased tourism expenditure Individuals — benefits and costs from changes in amenity, biodiversity, habitat, culture and/or heritage
2. Regulation of flows (a) Presence of regulatory structures along watercourses to regulate and divert flows (b) Water utility (or other organisations) responsible for operation of reservoir	Hydrology — reduces flow variability; reduces flooding frequency; changes the seasonality of flows; changes total flow; changes floodplain drying and wetting; reduces flow through the river mouth Habitat — changes in flow result in physical changes to the river channel and the habitats within it Water quality — changes the temporal patterns of the water quality Ecology — obstructs fish migration pathways; affects species and communities by changing the hydrology (for example, the flow regime); result in habitat losses	Landholders and businesses — benefits from reduction of flood effects Commercial and recreational fisheries — costs from decline in catch yield Tourism industry — benefits and costs from changes in visitor expenditure Individuals — benefits and costs from changes in amenity, biodiversity, habitat, culture and/or heritage
3. Weir pools (a) Weirs that create weir pools from which water is diverted (b) Water utility (or other organisations) responsible for operation of reservoir	Hydrology leads to — unseasonal protracted wetting in low level wetlands; raises watertables under nearby floodplains Habitat — creates stable water levels upstream creates fluctuating water levels downstream Water quality — constant, stratified water levels have the risk of algal booms Ecology — results in loss of bank habitat due to permanent wetting; reduces productivity	Commercial and recreational fisheries — costs from decline in catch yield Tourism industry — benefits and costs from changes in visitor expenditure Individuals — benefits and costs from changes in amenity, biodiversity, habitat, culture and/or heritage
4. Cold water dam releases (a) Releases of cold water from low level outlets in reservoir for irrigation (b) Water utility responsible for operation of reservoir	Water quality — decreases downstream water temperature; increases nutrient load and concentrations of natural toxicants such as hydrogen sulphide and heavy metals Ecology — leads to a decline in the number of fish species; changes species composition	Commercial and recreational fisheries — costs from decline in catch yield Tourism industry — costs from decline in visitor expenditure Individuals — costs from changes in amenity, biodiversity, habitat, culture and/or heritage

(Continued next page)

Table 2.5 **(Continued)**

Source	*Transmission*	*Effects*
5. Rapid changes in river height (a) Storage releases that cause rapid rises and falls in river height (b) Water utility responsible for operation of reservoir	Hydrology — affects flow regime; decreases bank stability; changes river morphology Water quality — increases turbidity and sediment transport (through erosion) Ecology — affects ecology by changing the hydrology (habitat, flow regime) and water quality	Commercial and recreational fisheries — costs from changes in catch yield and flow regime Tourism industry — benefits and costs from changes in tourism expenditure Individuals — costs from changes in amenity, biodiversity, habitat, culture and/or heritage

Sources: Ball et al. 2001; Gippel and Blackham 2002; Thoms et al. 2000.

Observability of irrigation water supply externalities

Many elements of water supply externalities are observable. The location of supply infrastructure is fixed and observable, and the organisations responsible for its operation and management are known. In some situations, the changes to environmental conditions can be measured — for example, flows are monitored at gauging stations along the River Murray, and daily flow data are publicly available from the Murray–Darling Basin Commission.

Although the sources of water supply externalities are generally observable, it is not always possible to identify all those who are affected, and even more difficult to know how much they are affected. In the case of increased groundwater discharge and changes to downstream water quality, externalities may be transmitted over long distances and with significant time lags.

Variation of irrigation water supply externalities across locations

Although sources of supply externalities are generally not diffuse, the effects may be geographically dispersed. In some situations, the source and effects are located in the reaches immediately upstream or downstream of the regulatory structure, such as the recreational and tourism benefits of reservoir waterbodies, or the decline in fish species due to cold water releases and the obstruction of fish passage. Given the spatial links between hydrological and ecosystem processes, however, effects could extend for a significant distance from the source or may be located far from the source, or in other parts of the catchment. An algal bloom, for example, may develop in the thermally stratified water of a weir pool, but could then spread hundreds of kilometres along a river away from its initial source. Further, the operation of large infrastructure — such as the Hume Dam on the River Murray —

can influence flow regimes of rivers and floodplains hundreds of kilometres downstream.

Table 2.6 **Examples of possible delivery externalities**

Source	*Transmission*	*Effects*
(a) What is the activity? *(b) Who undertakes this activity?*	*What changes to environmental conditions can occur?*	*Who can be affected? Are there external costs or benefits?*
1. Channel outfalls (a) Water that is released into a delivery channel but not diverted onto farms and that returns to the downstream environment (b) Operators of irrigation water distribution systems	Hydrology — changes the timing of river flows Water quality — channel outfalls may have different water quality (for example, lower salinity) from that of downstream flows Habitat — released water provides aquatic habitat that would otherwise not be available Ecology — changes the hydrology and water quality	Downstream users of water including agricultural producers, other industries and domestic consumers — costs or benefits, depending on water quality changes Commercial fisheries — changes in catch yield Recreational users — changes in catch yield and flow regime Tourism industry — changes in tourism expenditure Individuals — changes in amenity, biodiversity, habitat, culture and/or heritage
2. Leakage and seepage (a) Water that is 'lost' from distribution channels or that moves through the beds of distribution channels (b) Operators of irrigation water distribution systems	Hydrology — ponded areas form adjacent to channels; increases groundwater recharge; raises water tables Water quality — changes river salinity through saline groundwater recharge Ecology — changes occur due to changed river salinity	As identified for channel outfalls, and also: Agricultural producers — costs from increased waterlogging or benefits from pooled groundwater source Individuals (who may be producers) — costs from damage to regional infrastructure

Sources: DNRE 2002; Marsden Jacob Associates 2003.

The relationships between activities and effects can vary according to site-specific factors. Gippel and Blackham (2002) assessed the ecological effects of flow regulation along the River Murray and identified hydrological, geomorphic and ecological changes along eight distinct zones of the river. In all cases, the environmental changes varied in magnitude in different zones. For example, summer/autumn flows increased change upstream of Torrumburry Weir, but decreased change downstream. Young, Dyer and Thoms (2001), in a case study of the upper Murrumbidgee River, also showed that water resource development can lead to very different flow changes (and expected ecological effects) in different locations within the same catchment, and on the same river.

Some water diverted from rivers or dams is 'lost' in conveyance from storage to irrigator properties. Water losses in irrigation delivery systems can occur through channel outfalls, channel seepage and leakage, evaporation, bank overtopping, the ejection of water due to operational error, equipment failure or rainfall, metering error, and unrecorded use (Marsden Jacob Associates 2003). In some regions, distribution losses can provide positive externalities (Marsden Jacob Associates 2003) — for example, in the Coleambally Irrigation Area, leakage and seepage water from distribution channels has been an important source of water for some farmers, and channel outfalls provide water to downstream ecosystems and other users. The recent introduction of 'total channel control' technology has significantly reduced channel outfalls from the Colleambally Irrigation Area. The effects of delivery losses depend on many location factors, including soil types, delivery infrastructure, the distance that water is conveyed, and operating systems and practices.

Conveyance losses are not an externality for either the irrigation water supplier or irrigation water users. A water business accounts for the cost of conveyance losses through accounting provisions and in setting prices, and these losses do not reduce the volume of water ordered and received by an irrigator. A water loss through illegal activities benefiting the user (who may be an irrigator) which is not accounted for in transactions with suppliers is not considered an externality.

Variation of irrigation water supply externalities over time

Water supply and delivery externalities can be characterised by time lags between the operation of infrastructure and the effect. These time lags vary — some (such as the effects of reversed summer and winter flow levels) reflect short-term seasonality, whereas others depend more on longer-term natural climate variability including droughts and other extreme weather events.

In the case of water provision externalities, decreased (or increased) flooding frequency, for example, may lead to changes in wetlands over several decades, resulting in environmental outcomes, such as an increased rate of death of mature trees, the failure of seeds to germinate, a reduction in the abundance of floristic species, and a decline in fish and waterbirds. In contrast, local extinctions of some fish species in rivers may occur only a few years after dam construction impedes fish migration, although this depends on the lifespan of certain species.

In the case of delivery externalities, environmental changes transmitted through groundwater recharge (such as downstream salinity) may occur some time after water has been delivered if groundwater movement is slow. Damage to infrastructure due to saline groundwater is also likely to occur gradually. Positive externalities of delivery losses (see above), however, may occur soon after water is delivered, especially in established irrigation systems where several decades of irrigation has filled the soil profile with water.

Information on hydrological changes over time is generally more widely available than that for ecological effects. Historical and ongoing flow data are available at small time-steps, which enables analysis and modelling of the hydrological changes resulting from river regulation. In contrast, ecological consequences are less well understood, given the paucity of suitable data and because 'ecological responses are complex, often delayed, and can manifest in a location that is distant from the site of the hydrological disturbance' (Gippel and Blackham 2002, p. iv).

Knowledge and uncertainty about processes

Understanding how species and ecosystems respond to different flow scenarios is important to develop predictive capacity (Roberts 2002) — that is, to analyse the likely effects and tradeoffs (such as for recreational or productive values) from different supply systems or river and wetland management activities.

The instream hydrological changes resulting from reservoir design, the operation of regulating devices and the extraction of water for offstream use are well documented, both in general terms, and for individual river sites (box 2.1). Other studies have attempted to develop indicators to describe the links between ecological condition and flow regime (see, for example, Chessman 2001; Marshall et al. 2001; Young, Dyer and Thoms 2001).

The complex ecological responses to changing flow regimes are not fully understood (Young et al. 2002). The Murray–Darling Basin Commission's Sustainable Rivers Audit is the first program designed for the systematic and integrated collection of basin-wide ecological data. Many researchers have noted the need for further integration of the disciplines of hydrology and ecology, and for structured, comprehensive analysis of the ecological effects of flow regulation (Thoms et al. 2000; Marshall et al. 2001; Gippel and Blackham 2002). Thoms et al. (2000) also recommended further studies of the effects of water quality (including turbidity and temperature) on the functioning of the instream environment.

Another information problem is that studies have generally focused on monitoring and modelling the effects caused by *increasing* river regulation. River systems may be affected by hysteresis, which is the inability of an ecosystem to return to its original state following the removal of a shock or interference, such as a system of dams and weirs. If flows in a river are lowered as a result of irrigation diversions, for example, and then increased to their original level as a result of reduced irrigation, then aquatic, riparian and wetland environmental conditions may not recover to their original state, perhaps due to threshold effects resulting in irreversible changes to species, populations and ecosystems.

Box 2.1 Hydrological effects of flow regulation on the River Murray

Hydrological changes are generally measured by comparing current flow data to historical 'pre-regulation' data drawn from periods prior to the construction of storage and diversion structures. Commonly documented changes to flow regulation on the River Murray, for example, include:

- a reduction in the frequency of small to medium sized floods
- an unseasonal shift to high flows in summer and low flows in winter below large storages and upstream of major extraction infrastructure
- reduced total volume of flow due to extraction
- increased flow resulting from interbasin transfers such as the Snowy Mountains Scheme
- reduced velocity, increased depth and the removal of drying cycles upstream of locks and weirs
- modified day-to-day variation in flows (rates of rise and fall).

Sources: Gippel and Blackham 2002; Maheshwari, Walker and McMahon 1995; MDBC 2002; Roberts and Marston 2000; Thoms et al. 2000; Young 2001.

Understanding of the effects of conveyance losses is also incomplete, although there is some information on the volume of such water losses. Information on water delivery efficiency is available for several irrigation water providers (ANCID 2002), and for comparing open channels to piped systems (Harding and Viney 2000; ANCID 2002). In open channel systems typical of the southern Murray–Darling Basin, outfalls are frequently the largest source of losses, accounting for up to 45 per cent of total losses. In contrast, smaller amounts of water are thought to be 'lost' to evaporation (10 per cent) and seepage/leakage (5 per cent) (Marsden Jacob Associates 2003). Harding and Viney (2000) estimated that open channels in irrigation districts in northern Victoria lose 10 per cent of water to outfalls and 5 per cent to leakage and seepage, with figures much lower in mainly piped systems. The volume of water 'lost' in irrigation conveyance, however, is generally not known with precision for any specific cause (Marsden Jacob Associates 2003). Further, although guidelines have been established for measuring channel seepage (SKM 2002), the fate of 'lost' conveyance water — and its potential effects — is generally not well documented.

2.4 Applying the framework to irrigation water use externalities

This section identifies and discusses some of the characteristics of irrigation water use externalities, including waterlogging, land salinisation and downstream salinity. The sources, transmission and effects of some of the main externalities from irrigation water use are summarised in table 2.7. The sources and transmission of the externalities may overlap — for example, both downstream salinity and waterlogging may result from an application of irrigation water in excess of crop requirements, which increases recharge to the root zone.

Observability of irrigation water use externalities

The groundwater recharge and instream salinity changes that may result from one property's irrigation are generally not observable — irrigation salinity effects have diffuse (or non-point) sources. Several studies have modelled salt loads from different regions or subcatchments, however, based on information about soils, crop types and technology (see, for example, Heaney and Levantis 2001; Heaney, Beare and Bell 2001a). Combinations of these factors can be used as 'proxy indicators' of the potential salinity effects resulting from irrigation.

Like salinity, pollutant loads from individual properties are generally not observable. The ability to observe and monitor diffuse sources is further complicated by the many different forms of pollutants — for example, nitrogen and phosphorous can occur in inorganic or organic forms, and can be transported as dissolved or particulate nutrients (PC 2003). Further, in many regions, activities other than irrigation — such as land clearing, the loss of riparian vegetation, and overstocking — contribute significantly to instream sediment and nutrient loads. Modelling the physical processes, however, could provide information about the sources, transport and effects of salt and pollutant loads, which cannot be directly measured or observed.

Variation of irrigation water use externalities across locations

The type and severity of externalities can vary significantly across irrigation activities located in different regions. Different irrigation schemes — for example, coastal, river valley or floodplain schemes — tend to be associated with different environmental changes and effects.

Table 2.7 **Examples of possible irrigation water use externalities**

Source	*Transmission*	*Effects*[c]
(a) What is the production or exchange activity? *(b) Who undertakes this activity?*	*What changes to environmental conditions can occur?*	*Who can be affected? Are there external costs or benefits?*
1. Waterlogging and land salinisation (a) Application of irrigation water in excess of crop requirements, where drainage is insufficient to prevent groundwater recharge[a] (b) Irrigators	Hydrology — increases groundwater recharge and results in waterlogging Water quality — relocates salt in the soil to the soil surface Habitat — may cause freshwater habitats to become salinised Ecology — changes the ecology in response to increased groundwater levels and salinity	Agricultural producers — costs from waterlogging Household/business — costs from damage to buildings and infrastructure Individuals — costs and benefits from changes in amenity, biodiversity, habitat, culture, heritage, and indigenous values Commercial and recreational fisheries (and associated tourism) — costs from decline in catch yield following lost fish breeding sites
2. Downstream salinity (a) Application of irrigation water in excess of crop requirements, where drainage is insufficient to prevent groundwater recharge, leading to increased baseflow to streams[b] (b) Irrigators	Hydrology — increases groundwater recharge and the flow of water into streams; leads to saline water incursions into surface waterways Water quality — increases the discharge of salt into streams (where groundwater is more saline than river flows) Ecology — changes the ecology in response to increased stream salinity	Downstream water users including agricultural producers, other industries and domestic consumers — costs or benefits, depending on water quality Commercial fisheries — costs or benefits from increased or decreased catch yields[d] Recreational users — costs and benefits from changes in catch yield and flow regime Tourism industry — costs and benefits from changes in tourist expenditure Individuals — costs and benefits from changes in amenity, biodiversity, habitat, culture, heritage and indigenous values
3. Irrigation water pollution (a) Application of irrigation water in excess of crop requirements[a] Irrigation in conjunction with fertiliser and chemical application (b) Irrigators	Water quality — transports sediments, nutrients (nitrogen and phosphorous) and chemicals (pesticides and herbicides) to surface water and groundwater bodies and coastal regions Ecology — changes the water quality, contributing to eutrophication	Downstream water users, including agricultural producers, other industries and domestic consumers — costs or benefits depending on water quality changes Commercial fisheries — costs or benefits from changes in catch yields Recreational users — costs or benefits from changes in catch yields and ecosystem health Tourism industry — costs or benefits from changes in tourist expenditure Individuals — costs or benefits from changes in amenity, biodiversity, habitat, culture, heritage and indigenous values

[a] It is not possible to achieve 100 per cent irrigation efficiency. Some leaching to groundwater is considered necessary to prevent salt buildup in soils. [b] Increasing the baseflow to streams may be beneficial, where groundwater is less saline than river flows. [c] May be positive or negative, unless specified. [d] Several experimental saline aquaculture schemes, which intercept and pump saline groundwater, are being trialled or developed in Queensland, South Australia and New South Wales.

Sources: Ball et al. 2001; MDBMC 1999; PC 2003.

Floodplain irrigation schemes may be more susceptible to waterlogging, depending on drainage patterns and underlying watertables. Nutrient loads from irrigation in catchments draining to major inland rivers have the potential to affect aquatic ecosystems by contributing to eutrophication and algal blooms. In contrast, nutrient exports from irrigation schemes in catchments draining directly to the coast are more likely to have an effect on marine ecosystems (PC 2003). Nutrient loads also depend on the type of agriculture undertaken in each district.

Many factors influence the extent of salinity and explain its spatial variation, including groundwater recharge rates, underlying groundwater salinity, water use efficiency, soil types, the type and connectivity of aquifers, and the location of irrigation relative to waterways and land use (Beare and Heaney 2002). One reason for saline baseflow to rivers being more evident in the south of the Murray–Darling Basin is that this region is underlain by a sedimentary aquifer that has limited storage capacity and is largely saturated (MDBMC 1999). Rising groundwater levels may also have positive or negative on-farm effects, depending on local conditions. In some rice-growing regions in the Murrumbidgee region of New South Wales, for example, rising levels of relatively non-saline groundwater benefit rice production. In other regions, such as the Shepparton irrigation region in northern Victoria, shallow saline water tables have a negative effect on crop and pasture yields.

The effects of salinity and of pollutant and sediment loads in waterways are also likely to be geographically dispersed and to vary according to the location of the source. Further, downstream effects will vary from location to location given, for example, the differing tolerances of irrigated crops (Heaney, Beare and Bell 2001b).

Variation of irrigation water use externalities over time

A significant period may elapse between the application of irrigation water and its downstream effect. Generally, there is a considerable lag between land use changes and the mobilisation of salt to rivers and in the landscape (MDBMC 1999). Consequently, if irrigation practices were to change today, downstream river salinities might continue to increase as a result of past activities.

In contrast to dryland areas, where there are usually long lead times before salinity appears, irrigation salinity problems emerge relatively soon after irrigation commences. Salt mobilisation may occur more rapidly in irrigation districts where recharge rates are very high and the sources are close to the rivers (MDBMC 1999).

The time lag between irrigation and the effects of increased pollutant loads is also likely to vary. Increased phosphorus and nitrogen loads in rivers are more likely to lead to algal blooms during drier summers when flow is reduced and river water levels are low — for example, during the summer of 1991-92, when a 1000 kilometre algal bloom spread along the Darling River. In contrast, nutrient and sediment inputs to the Great Barrier Reef lagoon tend to occur in plumes following heavy rainfall. These pollutant loads may directly interfere with the reproduction and recruitment processes of coral and seagrasses, but may also have the longer term effect of diminishing the ability of coral to recover from acute effects such as cyclones (PC 2003).

Knowledge and uncertainty about processes

The physical processes associated with irrigation salinity are generally well understood and described. Salinity problems are caused by activities that have changed the hydrology of the landscape and accelerated the movement of salts into rivers and onto land. Changes to vegetation cover — especially the replacement of deep rooted perennial vegetation with shallow rooted annuals that have lower water requirements — have in many areas resulted in an imbalance between rainfall and plant water use (MDBMC 1999). This imbalance increases the amount of water entering groundwater systems (recharge). As watertables rise through naturally saline soils, potential salinity problems include increased discharge of salt into streams (where groundwater is more saline than river flows), waterlogging and the relocation of salt in the soil to the soil surface.

Knowledge about the ecological effects of instream salinity is incomplete. Although extensive studies have been conducted on instream and terrestrial ecological processes and biodiversity, the Murray–Darling Basin Ministerial Council (MDBMC 1999) and the Department of Land and Water Conservation (2000) noted that few studies have examined the effects of salinity on individual species, and that the effects of salt on natural systems is not generally well understood. Some species, such as fish species that evolved under saline conditions, have relatively high tolerances for instream salinity. Many Australian species, however, are adversely affected by increasing salinity, especially above the threshold salinity concentration of 1500 EC (MDBMC 1999). This threshold is approximately the upper limit of tolerance for many individual species, such as aquatic macrophytes and invertebrate fauna. Ecological processes are also affected as rising salinity causes the decline of the less salt-tolerant species from the landscape. Where trees die, for example, the physical structure of the ecosystem changes, and the habitat and breeding grounds of a range of flora and fauna disappear (MDBMC 1999).

The effects of waterlogging and land salinisation display threshold effects — that is, when the saline watertable rises to within two metres of the land surface, capillary action, transpiration by plants and evaporation at the land surface draw up the saline water and concentrate the salt. (Several studies have examined the effects of salinity on agricultural productivity and infrastructure — see, for example, Hajkowicz and Young 2002.) Salinity thresholds also exist for ecosystem health (box 2.2).

In general terms, the effects of increased nutrient and sediment loads on aquatic and marine ecosystems are well documented. Given the complexity of physical and ecological processes, however, it is generally difficult to attribute specific effects to individual sources. There are many sources of nutrients other than irrigated properties, for example. Further, nutrient loads are linked to sediment loads, and the risks to aquatic or marine ecosystems also depend on river flows and natural climate variability.

Box 2.2 **Salinity thresholds for ecosystem health**

Salinity exhibits threshold effects for ecosystem health (and presumably the values derived from ecosystems) at a concentration of about 1500 EC. At low concentrations, increasing salinity levels result in minor increases in ecosystem effects, because many species of invertebrates and aquatic and riparian plants can tolerate salinities up to 1500 EC. Beyond this concentration, however, several species exhibit adverse lethal and sub-lethal responses, including loss of vigour, reduced species diversity, and progressive depression of growth and plant size. Although 1500 EC is commonly cited as the 'threshold level' for ecosystem effects of salinity, the rapid increases in ecosystem effects generally occur over a range of 1000–2000 EC.

Source: Hart et al. 2002.

Knowledge about adjustment possibilities

To design the best response to an externality, the policy maker requires information about the costs imposed on all parties by the environmental effects, and the costs to all parties of reducing or avoiding the effects. The second kind of information is generally hard for policy makers to collect or estimate. Externality policies often place the burden of ameliorating externalities on those who, in some simple sense, are judged to have caused the externality. Yet, in an economic sense, each party has contributed to the externality since externalities are reciprocal. There is no justification on efficiency grounds for imposing the full external costs of an externality on the party designated as the polluter.

2.5 Summary

- Many of the externalities associated with irrigation water supply and use are complex and the links between sources and effects of environmental change are not always well understood. At times, it is difficult to identify, observe and measure effects from individual sources, and resulting changes in environmental conditions.

- Although there is considerable knowledge of relevant physical and ecological processes, significant knowledge gaps exist, especially in terms of predicting how ecosystems will respond to changes in water supply, use and other management activities.
- Specific characteristics of the environmental effects of irrigation water supply and use include the following:
  - It may be difficult to observe and monitor salinity and pollutant contributions from individual irrigators; in contrast, dams and weirs are fixed and observable, and their operations are known.
  - In many cases, environmental changes and effects are caused by multiple activities, including activities by agents not associated with irrigation supply or use. Irrigation water use may only be indirectly related to the unintended effects — for example, by influencing the operation of supply infrastructure.
  - The relationship between an activity and its effects can vary significantly with location. An individual activity may have many types of effects, and any individual effect could be the result of multiple activities. Further, the effects can be geographically dispersed or located far from the source.
  - In some situations, a time lag may exist between an activity and its effects. Time lags may be relatively short, ranging from immediate (such as changed flow regimes when a storage is constructed), to a few years (such as the effect of obstructed fish passage on species with short lifespans), or several hundred years (such as movement of saline water through slow moving aquifers).
  - The effects may be located relatively close to the source (such as waterlogging from raised watertables), far from the source (such as downstream users of surface water that has reduced water quality due to activities far upstream) or dispersed across significant distances (such as algal blooms).
- Externalities associated with environmental change also vary significantly in the extent to which the environmental changes are characterised by uncertainty. Further, there is variation in the level of understanding of how changes in environmental conditions result in unintended effects.
- There is no justification on efficiency grounds for imposing the full external costs of an externality on the party designated as the polluter.

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3 Externalities and potential responses

This chapter explains the economic concept and consequences of externalities associated with environmental change and discusses how they may be addressed by private actions or, if the benefits outweigh the costs, by government intervention. Section 3.1 details the economic effects of externalities and provides the conceptual framework for analysis. Section 3.2 discusses some factors affecting the likelihood of private action. Section 3.3 considers the case for government intervention. A brief discussion of core principles for assessing and designing policy instruments is provided in section 3.4. The section 3.5 considers efficiency and the choice of policy instrument in the presence of uncertainty. The final section discusses the theoretical effects of introducing a Pigouvian tax.

3.1 The economic effects of externalities

As noted in chapter 1, the divergence between private costs and benefits and social (external) costs and benefits associated with externalities can lead to an inefficient allocation of resources. The potential effects of negative externalities on market allocations are illustrated in box 3.1. Specifically, too much of the activity causing the externality may be undertaken, so:

- the price paid by consumers is too low and
- too much of the externality may be produced.

Since markets for one good are related to markets for other goods, the effects may, at times, be widespread.

3.2 The likelihood of private action

Where the action of one party affects another, the parties may be able to negotiate to achieve an efficient outcome, irrespective of the initial allocation, and in the absence of prohibitive transaction costs (Coase 1960). One possible outcome of two parties (a dairy and trout farmer) negotiating, using the example in box 3.1, is that the trout farmer pays the dairy farmer for some reduction in discharge if the dairy farmer has a ‘right’ to pollute. Alternatively, if the trout farmer has the right to clean water, the dairy farmer may pay the trout farmer for some level of continued discharge.

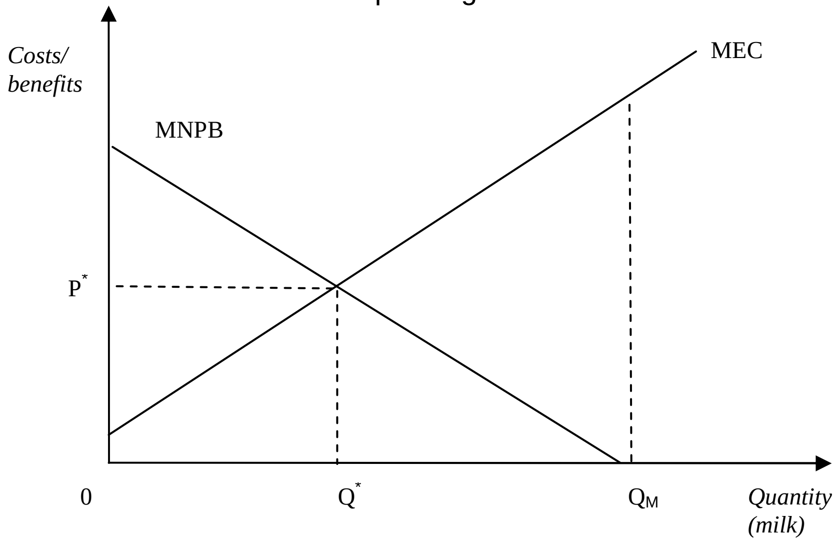
Box 3.1 **Equating marginal costs and benefits**

An upstream industry, such as a dairy farm, might impose costs, by way of reduced production, on a downstream industry, such as a freshwater trout farm, through discharge of waste. To simplify, assume that the waste is proportional to the quantity of milk produced; and that the trout farmer can do nothing by herself to reduce the costs.

The marginal net private benefit curve (MNPB) shows the minimum price that a dairy farmer is willing to accept to reduce milk production a little. It represents the reductions in profit when output varies. Q_M is thus the level of milk production that the dairy farmer would choose without considering the external costs of production. In other words, Q_M maximises the net private benefits or profit to the dairy farmer.

The marginal external cost curve (MEC) shows the maximum amount that a freshwater trout farmer is willing to pay for a reduction of milk waste to indicated levels. Given the MNPB and MEC curves shown, the level of production that could maximise the combined benefits to both parties is given by Q^*, where MEC equals MNPB. Thus the optimal level of pollution from an economic perspective is that emitted as a result of production at Q^*. This would be achieved if the trout farmer paid the dairy farmer, according to the schedule MEC, to reduce her output of milk and waste; or if the dairy paid the fish farmer, according to the schedule MNPB, not to exercise a legal right to force the dairy to stop pollution; or if a tax schedule, shown by MEC, were imposed on milk/waste (so the actual tax paid becomes 0P* x 0Q*).

If the downstream farm itself has abatement possibilities, then the story is more complicated than can be shown in a simple diagram.



Sources: Coase 1960; Pearce and Turner 1990; Wills 1997.

The arrangement that maximises the combined net benefits to both parties is where the marginal cost of discharge to the trout farmer equals the marginal benefit from discharge to the dairy farmer, irrespective of the initial allocation of rights. Waste, which is positively related to production, is still being discharged, but the costs of reducing discharges further exceed the benefits.

Incentives for and the likelihood of private action (and thus the applicability of Coasean solutions) may be affected by the degree of exclusivity or rivalry of the externalities. The likelihood of private action may also reflect the costs of identifying producers of, and those affected by, externalities, and of measuring the amount of externality produced and the extent of the effect. These factors are discussed below.

Exclusivity

Externalities are exclusive (or excludable) if all of the benefits can be captured by those undertaking production or mitigation action. Alternatively, the externality is said to be non-exclusive if it is costly or impossible to exclude people not contributing to production or mitigation action from receiving the benefits of that action. In this case, there is an incentive for individuals to 'free ride' on the actions of others — for example, by obtaining the benefits from others' negotiations that lead to a reduction in pollution. Externalities may be characterised according to the ability of individuals to 'free ride' on the benefits from externality production (in the case of positive externalities) or from the mitigation of externality effects (in the case of negative externalities).

Non-exclusivity reduces the likelihood of private action being taken to address an externality. Some private provision of non-excludable goods is still possible, however, as demonstrated by the existence of voluntary organisations seeking, for example, to enhance the biodiversity of rivers and streams. Notwithstanding such voluntary acts, less of a desired non-exclusive good is likely to be provided than if non-paying beneficiaries could be excluded (Wills 1997).

Exclusivity is affected by the specification of property rights and the ability to exclude individuals or groups who value access. It may be possible, for example, to exclude others from access to a lake if it is zoned for a specific purpose, or from use of river water if extractors must have a permit to extract water. The costs of such exclusion can be reduced by technological development and improved scientific information. The development of devices that scramble and decode television signals, for example, has allowed the creation of a market for pay television. Lower exclusion costs allow better definition and enforcement of property rights and therefore, the extension of markets (Wills 1997).

Rivalry

Externalities may also be characterised by the extent to which one person's enjoyment of the benefits of externality production or mitigation reduces or eliminates enjoyment by others (rivalry). Benefits derived by one individual from water quality improvements that enhance the ecological and aesthetic values of a river, for example, will not lessen the enjoyment of others. If, however downstream irrigators benefit from improved water quality by extracting water from the river, there is less water for other consumptive purposes; in this case, the benefits from external effects are rivalrous.

Some types of externality effects are non-rival up to a point (sometimes called the point of congestion) after which they become rival. The external benefits of a dam to recreational boaters, for example, may be non-rival up to some point, beyond which the addition of another boat diminishes the enjoyment by others.

Costs of identification and measurement

Private provision of goods and services can be hindered if the costs of identifying the producers of, and those affected by, externalities, and measuring the amount of externality generated and the extent of its impact are high (Wills 1997).

Non-point externalities (either source or effect) often involve a large number of agents spread over a wide geographic area (chapter 2). Generally, the transaction costs of coordination and negotiation increase as the number of parties involved and their dispersion (in terms of either the cause or effect of the externality) increase. These costs can pose a barrier to private action to mitigate the externality to an efficient level.

3.3 Is there a case for government intervention?

In some cases, private action might address an environmental externality, thus there would be no role for government. Neighbouring farmers, for example, might coordinate their timing of water use from an irrigation channel with limited capacity, if using water from the channel at the same time resulted in significantly lower water flows. Government actions might also 'crowd out' some more effective and efficient voluntary private sector activities to address the externality.

If private action fails to address an externality adequately, there may be a role for government intervention. However, the presence of an externality does not necessarily imply that there is a market failure which is worth correcting. In the case of a negative externality, the existence of an economically-relevant market failure depends on whether, on the margin, the private benefit from the activity generating the externality is less than the unrecompensed or external cost that it imposes on others. If, in contrast, the marginal private benefit exceeds these marginal external costs, then any further reduction, in the level of the externality-generating activity itself (for example, through a tax or regulation), will reduce aggregate net economic benefits. Beare and Heaney (2002) illustrated this for water (an input to production), where water availability may be restricted. They also considered the case of restricted supply and variable demand — for example, in response to changes in weather conditions.

Even when the market fails to provide the optimal level of a good or service, government intervention still may not be appropriate. The benefits of proposed government intervention may be less than the costs (which include the costs of policy development, administration, monitoring, enforcement and compliance). This may be so for a variety of reasons, including high information requirements, a lack of ability to properly enforce regulations, rapid technological change and evasive responses by targets of regulation. Policies intended to deal with one set of problems sometimes generate side or flow-on effects, which may be positive or negative. Any assessment of the merits of government action need to account for these wider costs and benefits.

3.4 Policy design and assessment

Four criteria for assessing and designing policy instruments are appropriateness, equity, effectiveness and efficiency (table 3.1). Transaction costs are important to consider and should not be overlooked in any analysis.

A proposed policy instrument is likely to be less effective and efficient if its design does not consider existing policies to address the problem (including non-regulatory approaches), or if it causes unintended distortions in the market.

Table 3.1 **Key principles for designing and assessing policy instruments**

Principle	*Description*
Appropriateness	Is government intervention warranted? Is the goal worth achieving?
Effectiveness	Does the policy achieve the stated objectives (that is, is it likely to result in desired changes in behaviour or achieve targeted outcomes)?
Efficiency	Taking into account the costs of designing, implementing and monitoring a policy (or transaction costs), does the policy achieve the highest net benefit of all the alternative policies?
Equity	Are there equity considerations?

Costs associated with designing, implementing, monitoring and enforcing a policy instrument include:

- information costs required by policy makers to design policy — for example, to set an appropriate tax level or quantity restriction
- administration, enforcement and monitoring costs incurred by agencies — for example, to assess auction bids, monitor adherence to contract terms or enforce non compliance with regulation
- search and negotiation costs incurred by market participants — for example, to search for other parties with whom to trade water allocation rights, environmental credits or pollution permits
- compliance costs — for example, costs incurred by irrigators when providing information to regulators regarding contract adherence.

These costs are sometimes collectively referred to as transaction costs. There are several definitions of transaction costs — for example, Williamson (1985) defined transaction costs as the 'comparative costs of planning, adapting and monitoring task completion under alternative governance structures', Arrow (1969), noted that they are the costs of running the economic system, and Gordon (1994) defined them as the expenses of organising and participating in a market or implementing a government policy.

Transaction costs consist of both ex ante and ex post costs. In the context of assessing policy options, ex ante measurement is appropriate. McCann and Easter (2002) noted that the costs involved with the final transaction are relatively easy to measure, but that those involved with initial information gathering and policy design enactment and implementation are rarely documented. The different features of irrigation water externalities (chapter 2) can have important consequences for the transaction costs of different policy instruments.

Defining the problem and target

A fundamental step in designing policy solutions to environmental problems is to be clear on the policy objective. In designing and assessing policy instruments to manage irrigation water externalities, the aim should be to alter behaviour so an appropriate level of external costs from changing environmental conditions are taken into account. Consequently, addressing an externality in an economic sense may not be consistent with achieving a predetermined environmental outcome.

In some cases, the scientific knowledge of the potential effects of environmental change is limited, which makes it difficult to design policy instruments to address marginal effects. Another challenge for policy makers is to identify the potential effects of new policies where existing management regimes are already in place to manage environmental change. Policies may interact in unexpected ways. ABARE (2004), for example, noted:

> … increasing water charges when water use is already constrained by regulation may simply impose costs without generating any net benefits. (ABARE 2004, p. 6)

Further, where there is limited measurement and reporting of environmental change, it can be difficult to assess whether existing management regimes are meeting environmental objectives. If there are several policies addressing the same environmental objective, it can also be difficult to distinguish the effectiveness of an individual policy.

An important decision for a policy maker is how much externality to address. It may not be efficient to attempt to address the entire externality, and a better approach may be to adapt to some level of pollution or environmental effects. The High Level Steering Group on Water (2000, p. 7) concluded that the goal should be to 'achieve an efficient and acceptable level of externalities in water resources rather than to eliminate such externalities altogether'. An efficient level of externality is achieved where the externality is abated (or adapted to) to the point at which the marginal cost of additional abatement (or adaption) is equal to the marginal benefit from such actions.

For the assessment and design of new policies to manage externalities, each externality needs to be defined beyond simply identifying instances of environmental change. Existing environmental 'standards' or 'acceptable levels' can define the point at which a level of environmental change becomes unacceptable to society and creates external costs. It may be difficult, however, to define an environmental 'standard'.

Where irrigators do not meet established environmental 'standards', then negative externalities may be generated. Where irrigators do more than is required and exceed environmental 'standards', then they can create positive externalities. Water utilities and irrigators should not be required to further address environmental change when that change occurs at or below the existing 'standard'.

Whom to target

Policy instruments to address externalities from the supply and use of irrigation water could be designed to target:

- parties potentially creating environmental changes (such as water utilities and irrigators)

- parties potentially affected by environmental changes (such as the community and recreational users)
- intermediaries (such as water utilities, farm input suppliers, farm output processors, and managers of recreational facilities) that may be able to influence the behaviour of parties potentially creating, and affected by, environmental changes.

Although irrigators may be the source of many types of diffuse pollution, such as nutrient discharges into water courses, it may not be efficient and effective to target them individually. Where there are a large number of parties creating diffuse externalities, it may be more cost-effective to target a small number of intermediaries (such as fertiliser companies) who have existing relationships and networks with those parties allowing them to more efficiently and effectively influence those parties' behaviours.

The choice of whom to target has distributional as well as efficiency consequences. Clarifying property rights is an important step in determining whether an 'impactor pays' or 'beneficiary pays' approach is adopted. By determining individuals' responsibilities, well-defined property rights implicitly reflect the extent to which the community has the right to be free of unwanted consequences of individuals' resource use decisions (Bromley and Hodge 1990). There are no simple efficiency grounds for determining how such rights should be allocated in the first instance (Coase 1960). Only if it is assumed that those suffering from 'pollution' have no adaptation options are there efficiency grounds to impose the full costs of pollution on the party designated as the 'polluter'.

The nature of the policy objective — whether it is restoring past damage and/or preventing future damage — may influence the choice of cost sharing model. Aretino et al. (2001) concluded that there is little economic rationale to charge retrospectively for biodiversity loss, because it is not possible to change past behaviour or correct past inefficiencies. Consequently, the efficiency gains from applying the 'impactor pays' principle may not apply for the case of degradation caused by past activities.

3.5 Efficiency and choice of instrument

If there is a sufficient case for government intervention, a wide range of options are available. One approach to assign a price to externalities is to use taxes, charges or subsidies (sometimes referred to as price based instruments). An alternative approach is to use quantity based instruments, which restrict the level of outputs or inputs. The market may then determine an efficient allocation of resources through a tradable permit system (Weitzman 1974).

There is no a priori reason to favour either price or quantity instruments, because the selection of either instrument depends on factors discussed below. Fullerton and Metcalf (2001) observed:

> …the same welfare-raising effects of environmental protection can be achieved … by a tax that raises revenue, the [command and control] technology restriction that raises no revenue, and even a subsidy that costs revenue. (Fullerton and Metcalf 2001, p. 251)

Factors that influence the choice of policy instrument include the supply and demand conditions and the level of uncertainty associated with measuring marginal abatement costs and benefits.

Supply and demand conditions

Beare and Heaney (2002) compared the relative efficiency of setting a constant tax with an equivalent fixed quantity restriction. With fixed demand for water and variability in water availability, they demonstrated that both types of instrument can, in theory, lead to efficient water allocation (assuming perfect information). With fixed supply and variable demand, however, taxes and quantity restrictions are not equivalent in terms of economic efficiency. Under these conditions, a fixed tax will not affect efficiency of market allocation, while a fixed quantity restriction may reduce the level of water use below optimum levels and generate deadweight losses. In both cases, the choice of instrument affects the distribution of returns from the use of the water allocation. While it is possible to set quantity based restrictions that vary with conditions influencing demand, the transactions costs of such a policy are likely to be high (Beare and Heaney 2002).

This analysis assumes that the parties involved are either unable or unwilling to negotiate privately, or that any tax charged on one party is returned to the other in a way that removes the incentive for further negotiation. Otherwise, if negotiation is possible and there is more than one externality producing or mitigating technology, a tax does not guarantee a ‘first best’ solution. In this case, an impost on one party without returning it as compensation to the other may result in an inefficient allocation of resources (Buchanan and Stubblebine 1962; Turvey 1963). This analysis also assumes certainty about the costs of producing or abating the externality.

Uncertainty

Uncertainty is an important consideration when assessing the benefits and costs of action. For some externalities, the science to describe the relationship between actions and their effects, such as the ecological effects of changing river flows is still emerging (chapter 2). This can mean it is difficult to estimate the benefits and costs of policy instruments, and there can be uncertainty about the costs of abatement and the size and distribution of the marginal benefits.

Weitzman (1974) examined the choice between a price instrument (a tax or a charge) and a quantity instrument such as a tradable permit system. If there is uncertainty about the benefits of producing or mitigating an externality, there will be uncertainty about the appropriate target level for the charge or quantity restriction. This uncertainty does not affect a comparison between taxes/charges and quantity instruments — the two instruments give the same (uncertain) result, because the result depends on the firms' abatement costs (Sterner 2003). If, however, the costs of producing or abating the externality are uncertain, the relative efficiency of the two instruments will differ (Weitzman 1974).

If the marginal cost of abatement is overestimated, a quantity restriction would be less stringent than the optimal one. If, instead, a charge is employed, it would be set too high, leading to excessive abatement. As Sterner (2003) notes, the effects of over- and under-regulation are not symmetric. If the marginal benefits of abatement are flat and the marginal costs of abatement are steep, the efficiency ('deadweight') losses due to a charge approach would be smaller than those for a quantity approach. The opposite is true when the benefit of abatement is steep and the marginal cost is flat: the dead weight loss due to a quantity regulation would likely be small, while the error caused by a price approach would be large (figure 3.1).

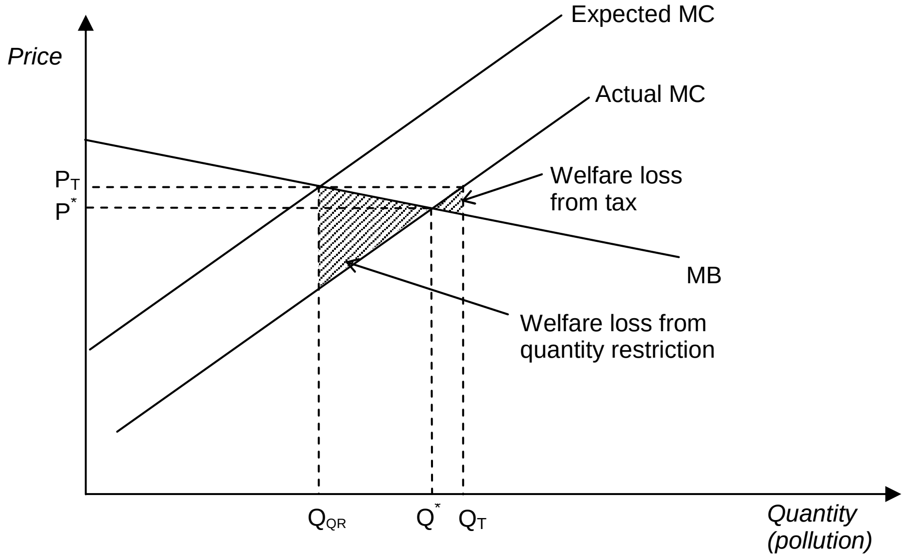
This analysis tends to suggest that a price instrument is more appropriate when the cost of abatement curve is steeper than the benefits curve (Sterner 2003). In contrast, when the marginal benefit curve is steep (as a result of environmental threshold effects, for example) relative to the marginal cost curve, then quantity restrictions are more appropriate (figure 3.1).

Distributional effects of policy instruments

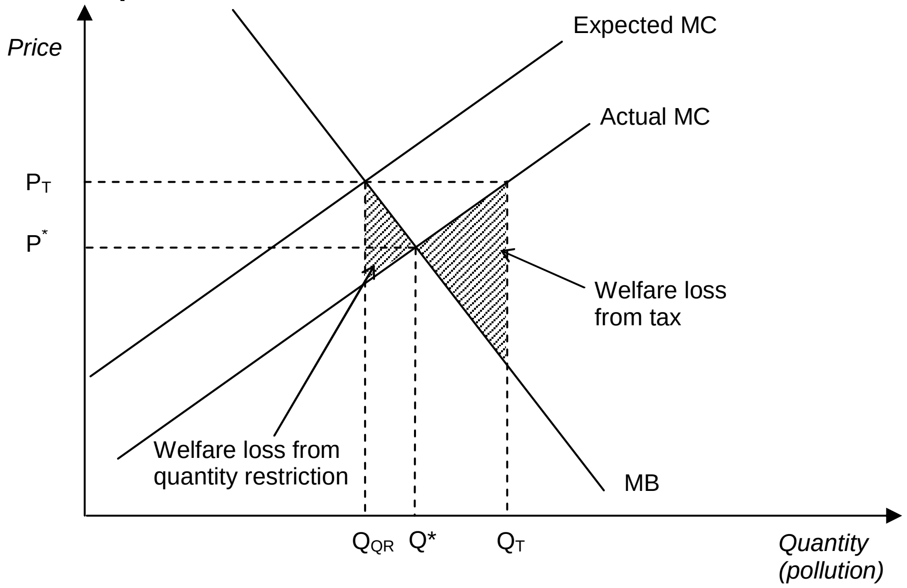
In theory, both a tax and a quantity restriction can achieve the same policy goal. The choice of instrument, however, will have different distributional effects. With a tax, the tax revenues are available to society (the use of such revenues is discussed in section 4.2). In contrast, if a quantity measure were used, scarcity rents equal to the value of the tax would accrue to the holders of water entitlements, mainly irrigators.

Figure 3.1 **Welfare losses from policy instruments when the costs of controlling pollution are uncertain**

Costs are steep relative to benefits



Benefits are steep relative to costs



Source: Derived from Adar and Griffin 1976.

These distributional consequences may influence the acceptability of the policy. Irrigators may prefer a quantity restriction to a tax, because scarcity rents provide some recompense for the reduction in the availability of water.

3.6 Externality charges and Pigouvian taxes

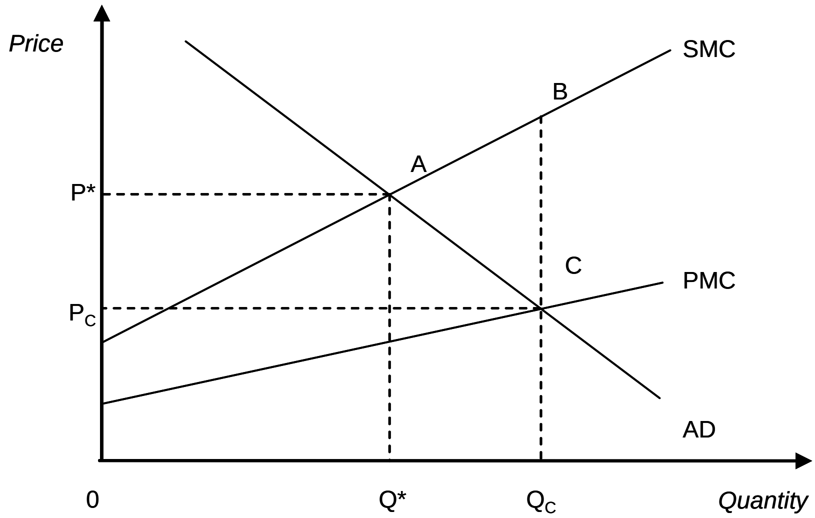
An externality charge of an appropriate level can be used to ensure the costs of negative externalities are transparent and provide appropriate incentives to economic agents. In many (but not all) cases, an externality charge on an input reduces the consumption of that input and thereby reduces the negative external effects of the input's use. The divergence between the net social benefits and the net private benefits can (but does not necessarily) lead to an inefficient allocation of resources. Such a charge (or corrective tax) on water delivery charges has often been proposed as one way to address environmental externalities from water harvest, storage, transport and use. The COAG requirements for utility charges to be based as full cost recovery, and include the cost of externalities, has been interpreted as requiring such a charge to be imposed.

In general, externality charges based on cost recovery reflect average costs — the total cost to be recovered is divided by the volume supplied. However, the marginal cost of an externality at the optimum level of output is unlikely to equal the average cost. If the marginal cost of the externality is greater than the average cost, an externality charge based on average costs will not reduce the level of use to the optimum level, but (as discussed later) is likely to increase efficiency. Conversely, if the average cost of the externality is greater than the marginal cost, water use will be reduced beyond the optimum level. The effect on efficiency will be ambiguous if the average cost is substantially above the marginal cost, and there may even be a loss of efficiency.

An optimal (or properly calibrated) Pigouvian tax schedule (after the British economist, A.C. Pigou) is equal to the marginal external cost (marginal damage) at each level of the various associated activities. In other words, the Pigouvian tax schedule inserts, between supply and demand, a tax wedge that is equal to the marginal external costs at each quantity. Unlike other taxes, introducing an optimal Pigouvian tax does not cause efficiency losses; to the contrary, it normally increases efficiency. The economic effect is similar to that of removing a distorting subsidy. In box 3.2, imposing a tax of $P^* – P_c$ results in an efficiency gain of the area ABC. (Unless explicitly stated otherwise, in this report the term 'Pigouvian tax' is used for an optimal Pigouvian tax schedule.) In this section, the theoretical effects of introducing a Pigouvian tax will be discussed.

Box 3.2 **Market allocation with external costs**

Assume the production of an irrigated commodity involves some externalities associated with the use of water. The private marginal benefit for the commodity is shown by the curve AD and the private marginal cost of producing the commodity (exclusive of externalities) is depicted as PMC. (It has been assumed that only one production technology is available and that no other ways of ameliorating the externalities are available than embodied in the social marginal cost function SMC. In practice, there may be a multitude of alternatives.)



The social marginal cost function SMC includes both the marginal cost of the externalities and the cost of producing the commodity. The marginal cost of the externality is the difference between SMC and PMC for a given quantity of production. If the only incentives to the producer are those signalled to it by the private opportunity costs of producing the commodity given by PMC, the producer would seek to produce Q_C. The social (or external) cost of producing additional units $Q^* – Q_C$ (area Q^*ABQ_C) exceeds the social value of those additional units (area Q^*ACQ_C) by the area ABC. This means that the area ABC measures the inefficiency caused by the externality, through the distortion of the irrigator's incentives for production of the commodity.

The net social benefit is maximised at Q^*, which is less than Q_C. At Q_C, the market price of commodity is P_C, which is lower than the optimal price at P^*. If some policy instrument or other approach leads to the production of the efficient quantity of Q^*, there will be an efficiency gain of ABC.

Sources: Pearce and Turner 1990; Wills 1997.

Pigouvian taxes and dynamic efficiency

A major advantage of Pigouvian taxes is that irrigators will be responding to the correct prices of inputs and outputs. Marginal changes in prices received, or paid, are likely to result in marginal changes in output, and in the use of water. This is because irrigators are responding to the social (external) cost of water. In contrast, if a quantity restriction is chosen, marginal changes in prices paid, or received, are only likely to result in changed output and water use if they exceed any scarcity rents.

While both Pigouvian taxes and quantity restrictions need regular review to reflect changing economic and environmental conditions, a Pigouvian tax has a greater capacity to respond to short term changes in economic conditions than a quantity restriction.

Introducing a Pigouvian tax may 'crowd out' some voluntary private sector activities. Irrigators who currently undertake voluntary activities to reduce externalities may no longer do so once they are paying a tax (Bazin, Ballet and Touahri 2004). Or, more generally, as Coase (1960) argued, there may be 'crowding out' of voluntary actions on the part of those suffering from negative externalities, to the detriment of economic efficiency.

Variation in efficiency benefits

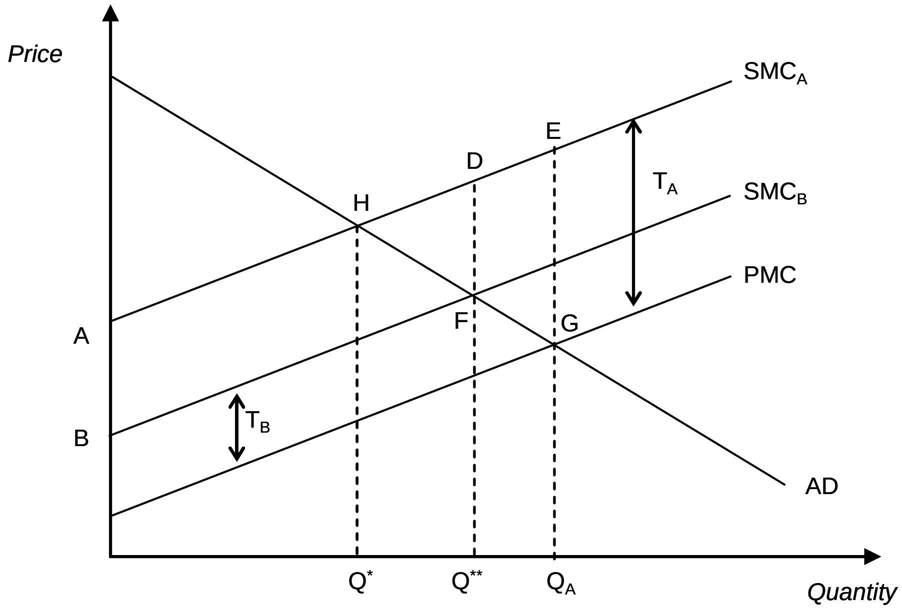
Introducing a Pigouvian tax will provide the greatest economic benefit when it is set at its optimum rate — that is, the marginal cost of the relevant externalities. However, there is often uncertainty as to the optimum rate. Nonetheless, a Pigouvian tax set below the optimum rate will improve economic efficiency.

In figure 3.2, if the actual social marginal cost is line SMC_A, the unconstrained private market outcome reaches equilibrium at G with the quantity of water being used (Q_A) being higher than the efficient (or socially optimal) level (Q^*) at H. If a Pigouvian tax is set at T_A (the difference between SMC_A and PMC at Q_A), efficiency would improve (by the area HEG).

Assume a government believes that the social marginal cost is SMC_B when the actual cost is SMC_A, and a Pigouvian tax is set at T_B (the difference between SMC_B and PMC at Q_A). The efficiency gain would be DEGF.

In general, the marginal efficiency gain from introducing a Pigouvian tax declines as the rate approaches the optimum rate. The marginal benefit of increasing the rate from T_B to T_A, for example, is HDF, which is smaller than DEGF.

Figure 3.2 **Improvements in efficiency from a Pigouvian tax**



3.7 Summary

- In economics, an externality is an activity's side effects or spillovers that are not taken into account in one party's (whether an individual or business) decision to undertake the activity and that affect another party's wellbeing.
- The mere presence of pollution does not necessarily mean there is an externality, and the optimal level of pollution is unlikely to be zero.
- Incentives for private action to address externalities are stronger when:
  - the externality is exclusive and there is limited ability to free ride on the actions of others
  - the externality is rivalrous
  - the costs of identifying the producers of, and those affected by, externalities and of measuring the amount of externality produced and its effect, are low.
- If private action through the market fails to address the externality, there may be a role for government intervention. The presence of an externality does not necessarily imply market failure, however, and government intervention may not improve the allocation and use of resources. Further, the benefits of any proposed government intervention may be less than the costs.
- Important criteria for assessing and designing policy instruments are appropriateness, effectiveness and efficiency. Any analysis needs to consider the

transaction costs, including information costs to policy design; administration, enforcement and monitoring costs incurred by agencies; search and negotiation costs incurred by market participants; and compliance costs.

- Any proposed policy instrument is likely to be less effective and efficient if its design does not consider existing policies to address the externality or if it causes unintended distortions in the market. A policy instrument may generate perverse incentives and cause changes in behaviour that detract from desired outcomes.
- A fundamental step in designing policy solutions to environmental problems is to be clear on the policy objective.
  - In designing new policies to manage externalities, analysis needs to go beyond simply identifying instances of environmental change.
  - Existing environmental 'standards' can define the point at which a level of environmental change becomes unacceptable to society and creates external costs.
- The choice of whom to target has distributional consequences, and the cost sharing choice once property rights and responsibilities are established can have efficiency implications.
- If there is uncertainty about the marginal costs of producing or reducing an externality, the relative efficiency of taxes/charges and quantity based instruments will vary:
  - A price instrument is likely to be more efficient when the marginal costs of abatement curve is steeper than the marginal benefits curve.
  - A quantity instrument is likely to be more efficient when the marginal benefits curve is steeper than the marginal costs of abatement curve.
- An externality charge based on cost recovery will, in general reflect average costs rather than marginal costs.
  - If the average cost is less than the marginal costs, water use may not be reduced to the optimum level, but efficiency is likely to increase.
  - If the average cost is greater than the marginal cost, water use will be reduced beyond its optimum level and there may even be a loss in efficiency.
- Introducing an externality charge equal to the marginal external cost at each level of the various associated activities (an optimal Pigouvian tax):
  - will equate the marginal private benefit and the marginal social (external) cost from an activity. Once achieved, this equilibrium implies that the marginal benefits to society from further reducing the externality will be less than the marginal costs

- might provide an incentive for the private sector to undertake abatement activities where these cost are less than the tax, if the private sector expects the level of tax in the future to adapt to the reduced external costs from abatement activities
- might reduce the activities that cause the externalities in some cases. If demand is relatively inelastic, however, imposing a Pigouvian tax may have little effect on the quantity demanded
- might 'crowd out' some voluntary private sector activities
- will have distributional consequences, and
- will require a great deal of data to properly design and calibrate the tax.

4 Implementing an externality charge for irrigation water

This chapter builds on the concepts introduced in chapters 2 and 3 and discusses issues involved in considering whether to implement an externality charge on irrigation water. The effects of imposing a charge or tax on water use when water supplies are constrained to varying degrees, and when irrigators face different market conditions for water, are discussed in section 4.1. Drawing on the framework developed in chapter 2, section 4.2 examines issues in designing a tax, including the suitability of a Pigouvian tax for addressing a particular externality, possible interaction with other externalities, determining the rate of a tax on irrigation water, the use of a tax to raise revenue, the use of tax revenues and the legal feasibility of a tax.

4.1 Effects of a tax on irrigator water use

Many factors can influence the effect of a tax on irrigators' use of water, including:

- existing mechanisms to address externalities
- the volume of water allocated to irrigators
- the extent to which trade can occur
- the size of the tax
- the price responsiveness for irrigation water.

There are many existing measures aimed at reducing externalities, including quantity restrictions (or constraints), and cost recovery for environmental activities undertaken by water utilities (chapter 1). In the southern Murray–Darling Basin, for example, the use of irrigation water is restricted by the 'Cap'. The Cap imposes a limit on the volume of water that can be diverted from rivers for consumptive uses. Irrigators can trade unused seasonal allocations and entitlements, with the market price of seasonal allocations often exceeding the utility supply charges. Thus, holders of water entitlements can earn scarcity rents (box 4.1). Appels, Douglas and Dwyer (2004) observed significant spatial and temporal variations in scarcity rents:

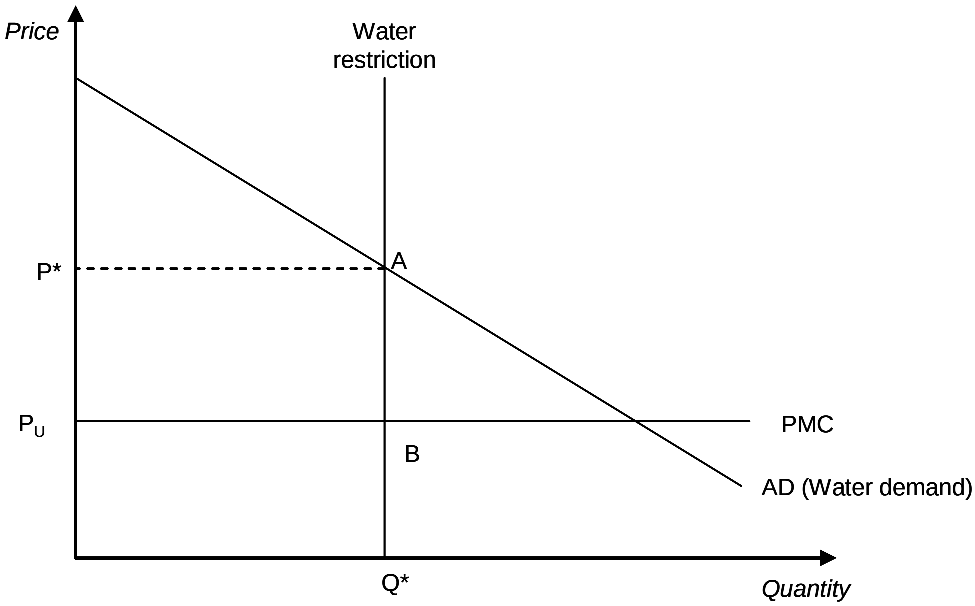
over the past three years, scarcity rents ranged from $50 per megalitre to $500 per megalitre.

In this section, the effects of a tax are considered when water supply is constrained for the cases of (1) no trade and (2) trade in irrigators' allocations of water.

Box 4.1 **Quantity restrictions and scarcity rents**

The ability to trade in unused seasonal allocations and entitlements, in the presence of restrictions on the availability of water can result in the market price of water exceeding the utility charges, generating scarcity rents for the holders of water entitlements (mainly irrigators).

In the simple diagram below, with water restricted to Q^*, at the equilibrium of P^* and Q^* the scarcity rent per unit of water is $P^* - P_U$ (where P_U is the utility charge). The value of water holdings, net of the utility charges, is P^*ABP_U.



A tax when there is no water trade

Without water trade, the initial allocation of water is likely to be suboptimal. The absence of trade means irrigators who could profitably use more water than they have been allocated are unable to purchase it, while other irrigators who cannot profitably use all their allocation cannot derive scarcity rents by selling it.

In the case of no trade, the effect of a tax on the quantity of water delivered to farms depends on the size of the tax, the elasticity of the aggregate demand curve and the total quantity of water allocated to irrigators (box 4.2).

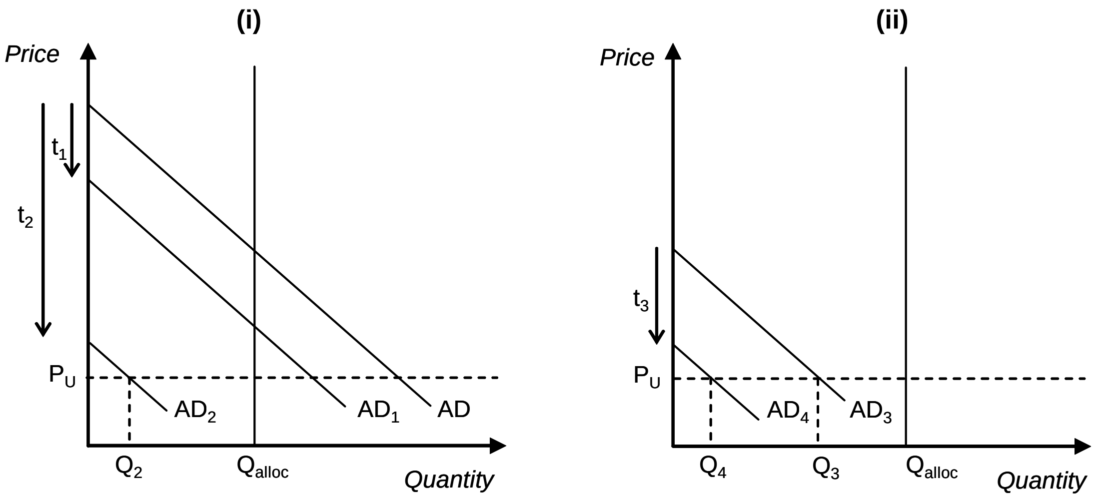
If an irrigator would, in the absence of the tax, use their full allocation and would prefer a larger allocation, a tax will reduce the total volume of water used only if it is large enough to reduce the marginal benefits of water use (after the tax) to below the utility charge. Responses by some irrigators are likely to be small or zero unless the charge is very high. A green tea farmer, for example, could face a reduction in profit if using even marginally less water significantly reduces the quality of their crop. This irrigator is likely to continue to demand the same amount of water from utilities to meet the quality standards — despite the externality charge — except in very wet seasons. Charges that are high enough to influence water use may involve significant adjustment costs.

Box 4.2 **Effect of a tax on the volume of water used by irrigators**

Assuming zero trade

In situation (i), where an irrigator is initially using full allocations ($Q_i = Q_{alloc}$) at a utility charge of P_u, a tax of t_1 shifts down the aggregate demand curve from AD to AD_1. However, a tax of t_1 will not reduce the volume of water used ($Q_1 = Q_i$). A tax of t_2, which shifts the aggregate demand curve to AD_2 is large enough to reduce the demand for water, making the quantity of water used (Q_2) less than Q_{alloc}.

In situation (ii), an irrigator is initially using less than the full allocation ($Q_3 < Q_{alloc}$). A tax of any size will reduce the total volume of water used; with a tax equal to t_3, water use is reduced to Q_4.



If another irrigator is initially using less than their full allocation of water, however, a tax of any size will reduce total water use. The magnitude of water use reductions depends on the elasticity of demand, which is likely to vary across industries, regions and seasons (Appels, Douglas and Dwyer 2004).

The use of water by irrigators relative to their allocations is likely to change in response to many factors, including seasonal conditions and the relative prices of their produce (Appels, Douglas and Dwyer 2004). In a wet season, the demand for water is likely to be low relative to supply and more irrigators may use less than their full allocations. In this situation, more irrigators are likely to respond to an externality charge by reducing their water use. On the other hand, relatively high prices of their produce could lead to more irrigators using all their allocation. In this situation, fewer irrigators are likely to respond to an externality charge by reducing their water use.

A tax when there is water trade

If trade in water occurs, the use of water is likely to be more efficient than in the case of no water trade, as water and other resources can be put to their highest value uses. Where a quantity restriction is binding and scarcity rents exist, an externality tax is unlikely to change the volumes of water traded or used on farms unless the tax exceeds the scarcity rents from trading the water. Irrigators will respond to the tax by reducing their demand for water, but also by increasing their supply. A small tax could result in a fall in the market price, but not necessarily affect patterns of water use (box 4.3).

In a wet season, if there are no restrictions to trade, it may be difficult to determine a tax's effect on patterns of water use across irrigation districts that trade with each other. Irrigators in one region may respond by decreasing water use, but sell their allocations, possibly resulting in increased water use in other regions.

Where there is a market for water (with sufficient participants), the effect of a tax on water use depends on:

- the size of the tax
- the relative slopes and positions of the aggregate water supply and demand curves before and after the tax (which, in turn, depend on the net private marginal benefits to individual irrigators of using water on-farm).

A tax imposed per unit on water delivered to farms reduces the marginal benefits of using water on farm (net of utility charges and taxes).

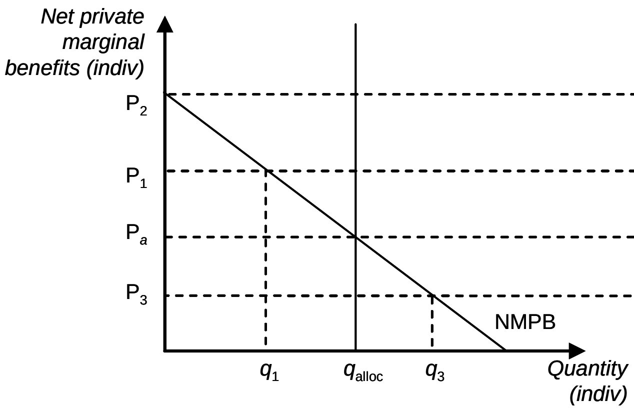
As illustrated in box 4.3, if a tax is sufficiently large (or the market price was zero without the tax, such as in a year with abundant rainfall), the market price of water could fall to zero with the tax. Less water will be traded and the overall quantity of water used by irrigators will fall. As ABARE noted:

> An important consideration for introducing charges for externalities is that the externality charge will only reduce the quantity of water demanded if the imposition of this charge removes any existing scarcity rents. (ABARE 2004, p. 2)

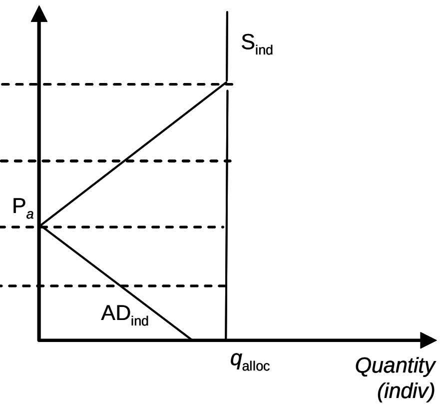
Box 4.3 **Total demand versus market demand for water**

An irrigator's demand for water is based on their net marginal private benefits (NMPB) gained from water use. For simplicity, it is assumed that utility charges are zero, so the 'market price' of traded water reflects scarcity rents available to holders of water allocations. At price P_a, the individual demands the full allocation (q_{alloc}) and does not supply water to the market. Above P_a the irrigator supplies water to the market — for example, at P_1, the irrigator uses q_1, and sells (supplies) the balance of their allocation in the market (quantity supplied = $q_{alloc} - q_1$). If the price rises to P_2 or above, the irrigator supplies all of their water to the market (quantity supplied = q_{alloc}). If, however, the price is below P_a (such as P_3), the irrigator increases water use to q_3, by supplementing the allocation with water purchases (quantity demanded = $q_3 - q_{alloc}$).

Individual's demand for total water

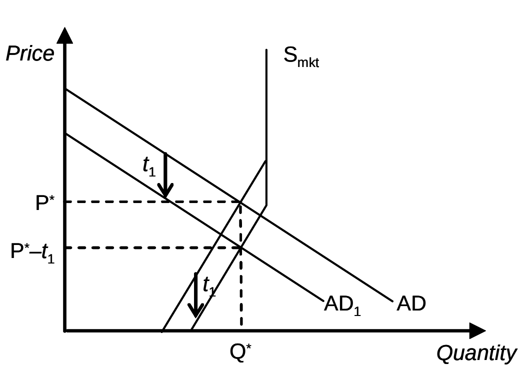


Individual's demand for, and supply of, trade water

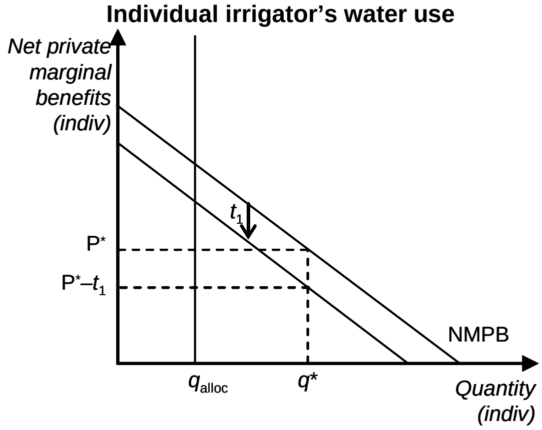


Aggregate demand and supply of traded water (the sum of all individual demands and supplies) shift down by the size of the tax when a tax is applied. In situation (i), where the price (P^*) is initially positive, a tax of t_1 (which is less than P^*) results in the price falling by t_1. There is no change in the quantity of water traded (Q^*). Because each irrigator's NMPB curves also fall by t_1, the tax does not have an allocative effect. The irrigator still uses q^* and buys $q^* - q_{alloc}$ in the market.

(i) Market for trade water



Individual irrigator's water use

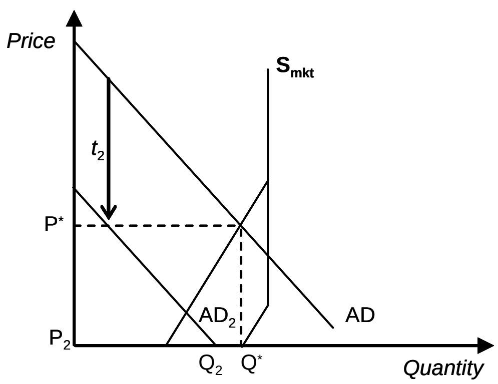


(continued next page)

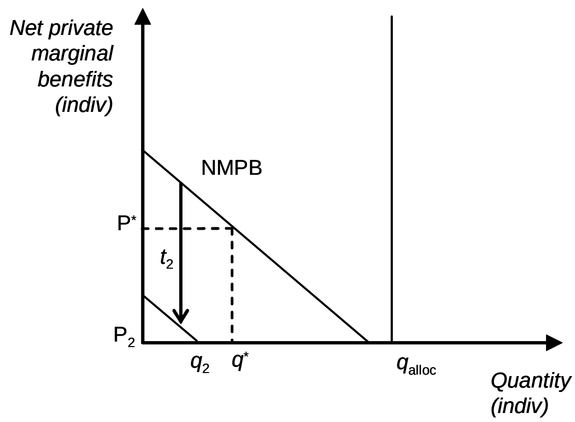
Box 4.3 **(continued)**

In situation (ii), where the market price (P^*) is initially positive, a tax of t_2 (where $t_2 > P^*$) results in the market price falling to zero. The quantity of water traded falls to Q_2. Given that fewer unused allocations are being traded, a tax of t_2 results in a reduction in the total quantity of water used. Some individual irrigators who (before the tax) could sell their unused allocations will (after the tax) be unable to sell some (or all) of their unused allocations. As a result of a tax t_2, the individual irrigator shown below reduces their water use from q^* to q_2.

(ii) Market for trade water

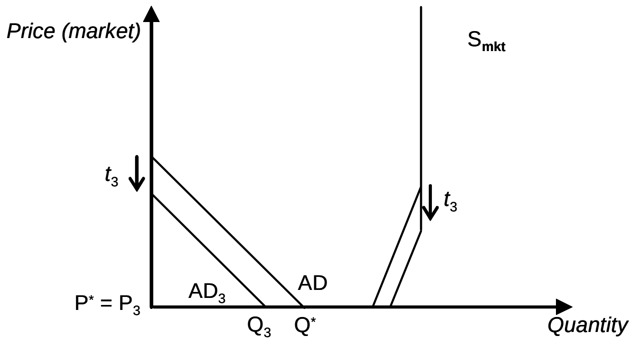


Individual irrigator's water use



In situation (iii), where the price (P^*) is initially zero and only unused water allocations are being sold, a tax of any size results in fewer unused water allocations being traded and a reduction in overall water use.

(iii) Market for water



Consequently, an individual irrigator is likely to be willing to supply water at a market price lower than that which existed before the charge. (The maximum volume that an individual can supply is limited by their initial allocation.) An irrigator is also likely to demand water only at a lower market price (box 4.3).

Nonetheless, introducing such a tax will ensure irrigators respond to the economic price of water.

If the quantity traded or used by individual irrigators does not change, there will not be any immediate improvement in economic efficiency from a tax (the quantity restriction in fact has constrained demand equal to, or lower than, the socially optimal level) — (although the tax itself is an efficient way of raising government revenue).

Even if a tax does not improve efficiency in the short term, it might provide incentives for dynamic efficiency improvements — irrigators might undertake abatement activities if they expect the level of tax in the future to adapt to the reduced external costs from abatement activities.

Distributional effects

Introducing an externality charge, as for all taxes, will have distributional effects. When there is a binding constraint on available water, distributional changes can be the main outcome, as noted by ABARE:

> The possibility exists that if demand is not particularly responsive to price changes, then attempts to deal with externalities through volumetric charges will only transfer income from irrigators to the government with no perceived benefits to society, unless the revenue generated is invested in mitigating infrastructure. (ABARE 2004, p. 19)

An implication of a reduction in the income of irrigators is that their net wealth would be reduced. The size of annual scarcity rents are likely to be an important component of the value of water entitlements. A reduction in scarcity rents because of a tax will reduce the value of the water entitlement.

ABARE (2004) noted that some irrigators may prefer the use of regulation to reduce water use, rather than a tax:

> Regulation … may … be the preferred option for irrigators. For instance, if a volumetric charge is needed to raise the price of water considerably before it will induce a management change … it may have been cheaper for irrigators to be regulated in order to manage the externality rather than pay the higher price for water. (ABARE 2004, pp. 16–17)

If governments use regulation to reduce water use (box 4.4), scarcity rents from holding water entitlements are likely to increase, and therefore the value of the entitlements themselves will also increase. In the short run, if the demand for irrigation water is inelastic, the resultant increase in scarcity rents might increase irrigators' wealth, even after accounting for a reduction in entitlements.

4.2 Issues in designing a tax

Drawing on the framework for analysing externalities associated with environmental change developed in chapter 2, this section considers issues in designing a tax on water use, including the suitability of an externality, the interactions with other externalities, challenges in determining the rate, use of such a tax to raise revenue, the use of the tax revenues and the legal feasibility.

Suitability of tax to an externality

Introducing a tax may be an appropriate policy tool for some, but not all, externalities. The objective of an externality charge or tax is to signal to the party undertaking the activity creating the externality the marginal social cost of that activity. An externality charge is most likely to achieve its objectives where there are clear links between the activity being taxed and the externality. In some cases, it may be easier to tax a proxy for the activity causing an externality rather than the activity itself (a ‘presumptive’ tax). It is easier to tax petroleum fuels, for example, than to directly tax exhaust emissions, and there is a clear relationship between the use of fuel and emissions (OECD 1996). As identified in chapter 2 there may be little direct relationship between the use of irrigation water and some externalities (for example, cold water pollution and flow regulation). However, with careful design, the indirect links may in some cases be sufficient to include the marginal cost of such externalities into a charge on water use.

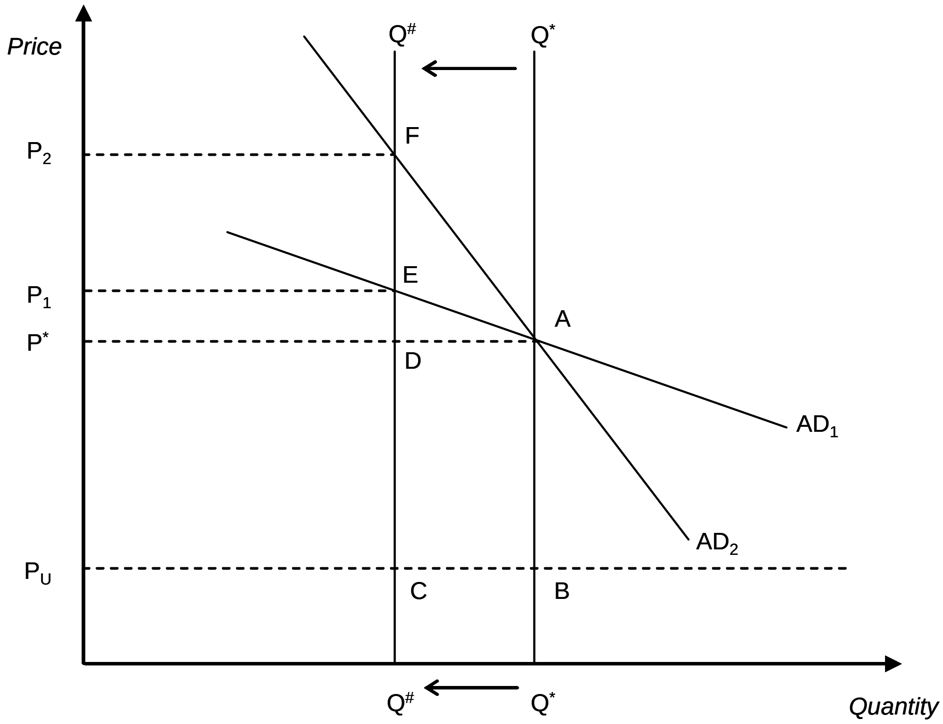
Some commentators have proposed taxes on agricultural products as the base of an environmental charge (box 4.5). However, as the OECD cautioned:

> Where the linkage between the tax base [or activity causing the externality] and the environmental damage is weak, the tax may fail to induce polluters to change their behaviour, and the tax may simply become the cause of more market distortions. (OECD 1996, p. 20)

A tax used to signal the marginal social cost of the activity creating the externality, is suited to externalities where the external costs are related to the level of activity (that is, marginal costs for each unit of output), rather than those having costs that are invariant to activity. (This assumes that there is nothing the person adversely affected by the environmental change can do to reduce costs, see box 3.1). Thus a Pigouvian tax might be suited to some irrigation water supply and use externalities (such an instream salinity). It is less suited to other externalities, such as obstructions to fish migration, which create an externality with their existence, regardless of the level of water use. Table 4.1 draws on the discussion of externality characteristics in chapter 2 to provide examples of negative effects that are/are not related to irrigation water use.

Box 4.4 **Changing the 'Cap' alters the value of scarcity rents**

If the amount of water available for allocation is reduced then the value of scarcity rents may either increase or decrease, depending on the elasticity of demand for water.



At the initial equilibrium of P^* and Q^* the scarcity rent net of utility charges per unit of water is $P^* – P_U$ (where P_U is the utility charge) and the value of holdings is P^*ABP_U. If the 'Cap' on water allocations is reduced from Q^* to $Q^\#$ then the increase in the scarcity rent depends on the characteristics of demand.

If, for example, demand was relatively elastic (AD_1), then the price would rise to P_1, the scarcity rent to $P_1 – P_U$, and the net value of water holdings would fall to P_1ECP_U (because ABCD is lost, while the smaller area P_1EDP^* is gained).

If demand is inelastic (AD_2), then the price would rise to P_2, the scarcity rent would increase to $P_2 – P_U$, and the net value of holdings would increase to P_2FCP_U (because the area ABCD is lost, but the larger area P_2FDP^* is gained). Water demand is generally considered to be relatively inelastic, suggesting that a small reduction of the 'Cap' may increase the total value of water holdings.

Interaction with other externalities

In designing any tax it is important to take into account any potential unintended consequences. Irrigation water supply and use can have both positive and negative externalities (chapter 2). Thus a tax related to negative externalities that reduces water use might have the unintended consequence of also reducing positive externalities. Water losses from the conveyance of irrigation water, for example, may benefit local producers by providing water through return flows and improve the functioning of natural ecosystems.

Box 4.5 **Alternative tax approaches**

The efficiency gains associated with Pigouvian taxes may not be achieved by other ‘environmental’ taxes. Environment Victoria, for example, has proposed a levy on goods produced from water drawn from the River Murray:

> … a river health levy on products, such as dairy foods, could contribute to the $1 billion the waterway needs to survive. … Supermarkets and food processors that make profits off the back of agricultural products grown from Murray river water should put something back into the river. (Environment Victoria 2005, p. 1)

It appears that the purpose of the levy is to provide revenue for environmental expenditure, rather than to reduce the use of irrigation water. The economic incidence of the tax is unlikely to be on supermarkets and food processors. A tax imposed on a business is either passed on to consumers as higher prices; input suppliers (including employees) as lower prices for inputs; or shareholders as lower dividends. Export markets largely determine the market prices of much agricultural produce (such as dairy products), so it is unlikely that much of the levy will be passed on to consumers. Rather, it is likely that much of the levy will be passed back to farmers as lower prices for their outputs. This might indirectly reduce overall water use to the extent that it results in farmers producing less agricultural output. While both a Pigouvian tax and the proposed levy are likely to reduce farmers’ incomes, in general the Pigouvian tax will encourage more efficient use of irrigation water.

An externality charge might also encourage actions that have a detrimental effect on the environment and longer term production, such as excess pumping of groundwater or the installation of farm dams to capture surface runoff before it enters river and groundwater systems. Many States have regulations, however, that limit the ability of irrigators to further access groundwater or build more farm dams for irrigation (Appels, Douglas and Dwyer 2004).

Determining the rate of a Pigouvian tax on irrigation water

The most difficult task in determining the rate for a Pigouvian tax on the use of irrigation is estimating the marginal costs of externalities (the volume of expected use is likely to be known by a water utility). This task is made more difficult by two factors:

- the marginal costs of externalities vary across locations and times
- limited information on the marginal costs of externalities.

Table 4.1 **Relationship between externalities and changes to irrigation water use**

Relationship between effect and the volume and timing of irrigation water use[a]	*Examples of effect*
Effect occurs regardless of the timing and volume of irrigation water use	Obstructed fish passage
Effect is indirectly related to the timing and volume of irrigation water use, which influences the operation of the supply system	Cold water pollution Flow regulation Delivery losses
Effect is related to the timing and volume of irrigation water use	Instream salinity Waterlogging on farm

[a] These relationships vary with location and time.

Variation across locations and times

An ideal Pigouvian tax would feature differing rates across different locations and times, reflecting the changing costs of externalities over location and time (chapter 2). The way in which water use (and the externality charge) should vary depends on the characteristics of the externality (or externalities), and on the characteristics of water demand for different irrigators (Appels, Douglas and Dwyer 2004).

Water utility charges already vary according to location, both between and within utilities. Goulburn-Murray Water, for example, had seven charging zones for gravity water in 2004–05. In most cases a single utility is responsible for the use of irrigation water in an individual valley or irrigation district. The marginal economic cost of externalities associated with the use of irrigation water could be estimated for each valley or district where irrigation is significant. Where valleys or districts are interconnected (as in the southern Murray–Darling Basin), externalities can occur across these valleys or districts. Therefore it is necessary to consider externalities across the entire network, rather than just those that may affect an individual valley or district. While spatial differences in the cost of an externality within valleys could also be estimated, it would be desirable that such estimates are based on the charging zones of the relevant utility. Unless the spatial costs of a particular externality are known to vary significantly within a valley, the costs of gathering the information to allow differential charging within a valley may outweigh the benefits.

Most irrigators have to 'order' the delivery of irrigation water from their utility. In such cases, it is possible to design tax rates that would vary within a year (perhaps on a weekly or monthly basis). However, unless there is a significant difference in the cost of externalities between time periods, there may be little benefit in imposing a Pigouvian tax with a rate varied within a year. Further, because irrigators can alter the timing of ordering water, there may be unintended consequences, such as a surge in orders for water immediately before an announced price increase.

Limited information on the marginal costs of externalities

Information deficiencies make it unlikely that the marginal costs of externalities associated with the use of irrigation water can be accurately determined (OECD 1996). In Australia, for example, there appear to be few studies that would provide policy makers with an indication of the likely level of a tax. In the absence of such information, it will be difficult to calibrate (set a near-optimal) Pigouvian tax. Caution should be exercised in setting the rate, as too high a tax rate may lead to efficiency losses, rather than gains.

Review of tax rate

The rate of tax should be regularly reviewed, for three reasons. First, the marginal costs of externalities are likely to change over time. In the short run, firms may reduce production of the commodity using water and/or change their input mix. In the long run, firms may choose to introduce changes in technology or to relocate their enterprises, reducing the social cost of using irrigation water as well as the private production costs (OECD 1996). Second, better estimates of the marginal costs of externalities may become available, which may lead to a revised tax rate. Third, regular reviews should provide incentive over the longer term for irrigators to consider ways of reducing externalities for a given level of water use (if the marginal costs of abatement are less than the marginal reduction in externality). If the tax rate is fixed, there may be less incentive for abatement.

Use of a tax to raise revenue

Assuming the demand for irrigation water is relatively inelastic in the short term (Appels, Douglas and Dwyer 2004), imposing a tax on irrigation water may appear to be an efficient means of raising revenue beyond that justified to correct an externality. Ramsay (1927) proposed that it would be economically efficient to impose taxes on commodities at rates proportional to the sum of the reciprocals of the elasticities of demand and supply of final consumption goods — that is, a relatively high rate of tax could be imposed on commodities with inelastic demand without having large effects on economic efficiency.

When considering Ramsay’s proposition, three further factors need to be considered. First, Ramsay’s general proposition applied to taxes on final consumption (in his words, 'uses of income'), not taxes on intermediate inputs. Stiglitz (1988, p. 499) considered the case where a tax (other than a Pigouvian tax) falls on both intermediate and final consumption: 'whenever a commodity is used both by businesses and consumers and the tax is imposed on both (businesses are not exempted), there is a loss in productive efficiency'. Stiglitz did not argue that taxes (other than a Pigouvian tax) should never be imposed on intermediate inputs, but rather that such taxes should be imposed only when they are the most efficient method of achieving a policy goal. Where excises (whose main purpose is to raise revenue) are currently levied on business inputs in Australia (for example, excises on petroleum products), the Australian Government rebates some of the excise to certain businesses (for example, agriculture and transport).

Second, Ramsay proposed imposing taxes on all final consumption goods, not just those with low elasticities. Imposing taxes on some consumption goods, but not others, would increase efficiency losses. Third, Ramsay specifically excluded consideration of the distributional effect of such taxes. If it were assumed that irrigation water is mainly used to produce food, and that producers can pass on some of the tax to consumers, the resultant price increases would fall more heavily on low income households than high income households. A more likely effect (assuming that marginal Australian agricultural production is exported) is that producers could not pass on cost increases to consumers in the short run, and the tax would fall on farm households.

A final consideration is the possibility of 'cascading' taxes — that is, when taxes are imposed at multiple points in the production chain, leading to 'taxes on taxes'. A cascading of taxes is undesirable because it tends to magnify the efficiency losses that result from most taxes. Given that the purpose of a Pigouvian tax is to ensure producers react to a price that includes social costs, the tax ensures the affected input is correctly priced; then, imposing a Pigouvian tax that correctly reflects social costs does not cause efficiency losses. If, however, the tax were imposed at too high a rate (perhaps reflecting uncertainty about the valuation of an externality), the excess component might lead to efficiency losses, which could increase if cascading then occurred. An exception would be if producer demand for the taxed input were inelastic, in which case no efficiency loss would occur.

Use of tax revenue

Assuming a tax were imposed, what are the options for the revenue? One option, referred to as the 'double dividend' hypothesis, may be to use the revenue raised to reduce, or retire, an existing and inefficient revenue raising tax. Proponents of the 'double dividend' hypothesis argue that the economy would benefit from the correction of the implicit subsidy associated with the externality, and also from the reduction in deadweight losses associated with the existing distorting tax.

Such a response, however, could prompt irrigators and others to question why the proceeds of a tax being imposed to correct an environmental problem were not being spent to correct the externality. A externality tax may be more acceptable to irrigators (and others) if the revenue is 'hypothecated' to (or earmarked for) environmental problems associated with the externality (ABARE 2004). Hypothecation could thus increase the tax's acceptability in those cases where associated expenditure could reduce tax levels in the future. Consider an externality associated with salinity: if the tax revenue funds a salt interception scheme, the externality could be diminished (or cease) once the scheme was completed, and the tax could then be reduced (or removed). In some cases, however, the revenue may not be easily used to reduce an externality (for example, where the externality is associated with water storages).

Several factors require careful policy consideration if a decision is made to hypothecate environmental taxes. First, the revenue raised by a tax may be more, or less, than the optimal level of expenditure on remedying and/or preventing environmental damage. Further, a hypothecated tax may tend to 'crowd out' both government and private expenditure on an environmental externality — the tax and associated expenditures could be perceived as having 'fixed' the problem (Bazin, Ballet and Touahri 2004).

The annual revenue raised by an environmental tax is likely to vary with the use of irrigation water between years. A tax of (say) $1 per megalitre might raise up to $16.7 million, assuming water use in agriculture of about 16 700 gigalitres (which was the use in 2000-01, the latest non-drought year where data are available). This estimate is likely to be an upper bound; demand for water in some locations is likely to respond to the price change from the tax. However, water use in agriculture, and therefore potential revenues, was 37 per cent lower in 2002-03 due to drought. The variation in water use is likely to be greater within some individual valleys and irrigation schemes.

Legal feasibility

The legal distinctions between, and constitutional provisions for, taxes, excises and charges have important implications for environmental taxes, charges and regulations. The definition of taxation terms has been the subject of debate, particularly from a legal perspective. The Australian Constitution and case law require different types of government impost to have certain characteristics, to meet the legal definitions of tax, charge and excise. A government impost that fails to satisfy the relevant legal definition may be challenged and declared invalid.

Only the Australian (Commonwealth) Government can impose an excise duty (s. 90, *Commonwealth of Australia Constitution Act 1900*). The High Court has defined an excise duty as:

> duties of excise are taxes on the production, manufacture, sale or distribution of goods, whether of foreign or domestic origin. Duties of excise are inland taxes in contradistinction from duties of customs which are taxes on the importation of goods. (*Ha v State of New South Wales* 1997 368)

Irrigation water is used in the production process, and therefore a tax imposed on irrigation water may be considered an excise duty. If this were the case, the States and Territories could not legally impose such a tax.

An important limit on the Australian Government's taxing powers is that taxes must not discriminate between States, or parts of States (s. 51(ii), *Commonwealth of Australia Constitution Act 1900*). A tax that attempted to levy differential rates of taxation to reflect regional differences in the size of externalities may thus face legal challenges. Environmental taxes that have different impacts on different states or parts of states may not be considered discriminatory if their different impacts are clearly based on differences in environmental conditions or in environmental impacts from the taxed activity, but the legal position on such taxes has not been clearly defined to date.

While these restrictions may make the introduction of a tax more difficult, there are precedents that may assist in design:

- In 1997, the High Court ruled that the New South Wales tobacco licence fee was an excise duty (*Ha v the State of New South Wales; Walter Hammond v the State of New South Wales* 1997). The decision invalidated many State and Territory franchise and licence fees, particularly on alcohol and tobacco. Since that date, the Australian Government has imposed excise duties on alcohol and tobacco, and remitted the revenue to State and Territory governments.
- The Australian Government imposes uniform excise duties on diesel fuel. Nonetheless, the Energy Grants Credit Scheme (an expenditure measure) provides rebates for diesel used by vehicles with a gross vehicle mass between 4.5 and 20 tonnes when used outside 'metropolitan areas'.

The Victorian Government recently announced it will require water utilities to:

> … contribute funding towards water related initiatives that seek to promote the sustainable management of water and to address adverse impacts to the environment associated with its use.

> It is proposed that each authority will be required to pay an annual environmental contribution based on a percentage of its existing revenues. Once this amount has been determined, this will become a fixed amount that the authority will be required to pay annually over four years. (Victorian Government 2004, p. 129)

The Victorian Government expects water utilities to pass this charge onto water users.

> This is likely to increase prices by an average of five per cent for urban water customers and two per cent for rural customers. (Victorian Government 2004, p. 129)

The main feature of this arrangement that may distinguish it from an excise tax is that it is a fixed charge based on the past revenues of individual utilities. Constitutional validity is a complex issue which would require close consideration of all aspects of the legislative scheme.

4.3 Summary

- A number of factors can influence the effect of a tax or charge on irrigators' use of water, including the volume of water allocated to irrigators, seasonal conditions, the extent to which trade can occur, the size of the tax and the price responsiveness of demand for irrigation water.
- Responses to an externality tax would vary across irrigators, across irrigation districts, within seasons and from year to year.
- A tax will not necessarily result in changes to water use, because it affects both the irrigator's demand for water and their supply to the water market.
- If, however, the market prices of water with and without the tax are positive (that is, scarcity rents exist without and with the tax), a tax will have no influence on the quantity of water traded or used by individual irrigators.
- To the extent that scarcity rents vary over time, such a tax might improve efficiency at times when these rents are less than the tax.

A tax could be an appropriate policy tool for some, but not all, externalities. In general, such a tax will be most appropriate where the marginal cost of an externality is directly related to the use of irrigation water, and nothing else. An externalities tax will be less appropriate where there is little link between the externality and the use of irrigation water.

- Determining the optimal rate of a tax is difficult due to differences in the marginal costs across locations and times and limited information on the marginal cost of externalities.
- Once the rate of a tax is determined, it should be regularly reviewed.

- Allocating revenue from ('hypothecating') a tax to address environmental problems associated with the externality would require careful policy consideration. The revenue raised by such a tax may be higher, or lower, than the optimal level of expenditure on the environmental externality. A hypothecated tax may also tend to 'crowd out' both government and private expenditures on the environmental problem. However, using the revenue raised to address the externality is likely to make such a tax more acceptable.
- Imposing an externality tax or charge that has the features of an excise tax might present utilities and governments with legal uncertainties.

APPENDIX

A Irrigated agriculture

This appendix discusses the costs of irrigation water (section A.1) and the operation of markets for trading water in Australia (section A.2). A clear distinction is drawn between prices or charges for water paid by irrigators to utilities, and market prices paid for seasonal allocations and water entitlements. Information from Goulburn-Murray Water, a water utility in the southern Murray–Darling Basin, is used to illustrate the operation of irrigation water supply and use systems.

A.1 Economic costs and water charges

In supplemented irrigation districts, utilities charge irrigators for the water allocated and/or delivered to farms. These charges do not represent all the economic costs associated with the supply and use of irrigation water — the charges include some of the costs of supply but not the costs associated with use. Supply costs can include:

- cost of capital of the infrastructure
- operational and maintenance costs of supply, including infrastructure maintenance and delivery operations
- environmental management costs and third party effects associated with the supply (externalities)
- costs associated with managing congestion
- losses in water volumes from storing and delivering the water.

Utility charges are designed primarily to recover operational, maintenance and some capital costs. They do not reveal the opportunity costs of water use.

Charging regimes vary across irrigation districts in the southern Murray–Darling Basin. Several utilities, including Goulburn-Murray Water and Murray Irrigation Limited, charge irrigators a two-part tariff consisting of:

- a fixed component — charges based on the volume of water specified to be the irrigator’s water right or entitlement
- a variable component — charges on either the volume of water allocated or delivered during the irrigation season.

In some irrigation districts, these charges are further differentiated across local districts to reflect the relative costs to the utility of storing and delivering irrigation water to each district. For example, Goulburn-Murray Water's 2003-04 fixed and variable charges for gravity irrigation varied across the eight irrigation districts that it supplies:

- the infrastructure access (fixed) charge (for each megalitre of water entitlement) varied from $13.20 for the Pyramid Hill-Boort district to $23.22 for the Shepparton irrigation district
- the infrastructure use (variable) charge (for each megalitre of water used) varied from $5.62 for Shepparton to $11.05 for the Campaspe irrigation district.

Different jurisdictions take different approaches in charging for costs associated with environmental management activities. For example, in South Australia and the ACT, explicit environmental management charges are levied on the amount of water consumed. Other jurisdictions do not appear to have an explicit charge for environmental management costs. Some utilities have explicit levies for these costs: for example, Murrumbidgee Irrigation Limited charged irrigators $145 per year to recover costs of running its Envirowise program (DNRE 2001). Most utilities appear to incorporate the costs they incur in managing environmental and natural resources in general supply charges.

ANCID (2002) estimated that in 2001, the average charge for irrigation water by utilities was $23.51 per megalitre, ignoring fixed supply charges — the last megalitre delivered is generally charged the same as the first megalitre delivered. Historically, subject to water availability, irrigators have been able to purchase water in excess of their allocation at the same supply price as their seasonal allocations (in wet years, for example, water managers may set allocations above 100 per cent allowing irrigators requiring additional water to purchase the differential as an excess but in proportion to their base entitlement).

A.2 Trade in irrigation water

Depending on the pattern and scale, water trading may be a key factor in determining externalities of water supply and use, and in assessing and implementing potential management options. In a market where water is freely traded among competing users (including non irrigators), the clearing price will reflect the private opportunity cost of the water. The full or social opportunity cost of water will be the difference between the marginal benefit that could be gained by using the water and the marginal costs of supplying the water together with marginal external costs associated with the supply and use of the water (Beare and Heaney 2002; Rogers, Bhatia and Huber 1998).

Irrigators can purchase water from utilities, and trade seasonal water allocations and the underlying long term water entitlements. Trade in water allocations, sometimes referred to as ‘temporary trade’, occurs when irrigators trade all or portions of their seasonal allocation to other irrigators (usually within the same irrigation area or utility supply district). Trade in water entitlements, sometimes referred to as ‘permanent trade’, occurs when entitlements to future water supplies are traded from one party to another party. In the three major irrigation districts of the southern Murray–Darling Basin (the Murrumbidgee Irrigation Area, the Murray Irrigation district and the Goulburn-Murray Water district), trade in water allocations accounted for around 20 per cent of total allocations, while trade in water entitlements accounted for less than 2 per cent in 2002-03 (Appels, Douglas and Dwyer 2004).

Restrictions on the trade of irrigation water are a key reason why both allocation and entitlement prices are unlikely to reflect the full opportunity cost of water. Regulatory or administrative restrictions are imposed at both the regional and State level to retain water within irrigation systems due to concerns about the consequences of water rights being traded out of certain areas (for example, Appels, Douglas and Dwyer 2004; Bell and Blias 2002; and Goesch 2001).

Some restrictions on trade are also imposed for environmental concerns, including for the maintenance of wetland biodiversity and the management of salinity. Other restrictions reflect physical congestion constraints, which limit the volume and rate at which water is able to flow through sections of the supply network. Sometimes these restrictions may be inter-related, such as congestion constraints also having environmental implications. For example, the flow capacity of the River Murray is reduced to around 8500 megalitres per day through the Barmah Choke as flows in excess of this cause flooding of the surrounding red gum forest. Flows through the Barmah Choke are controlled to prevent environmental effects that would be caused by unseasonal flooding.

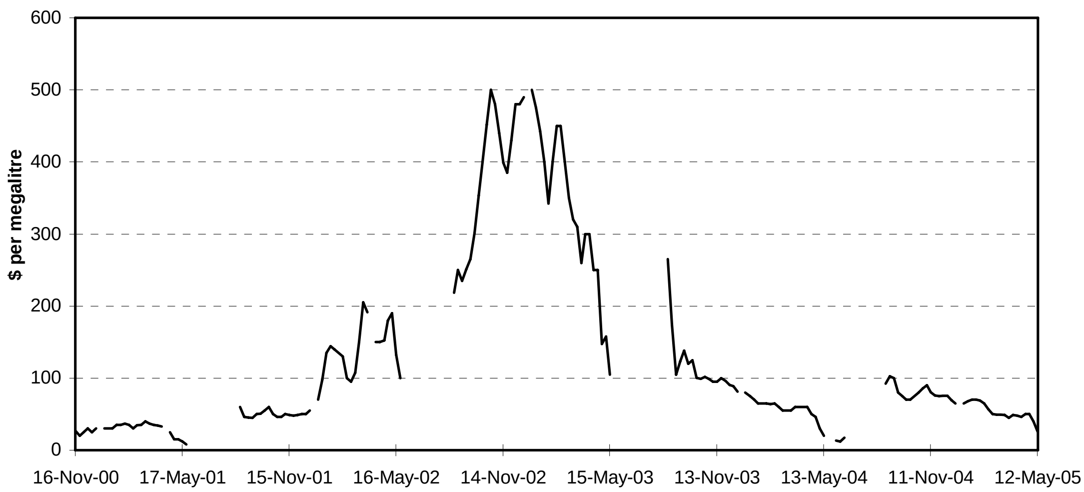
Trade of allocations

Irrigators can capture rents by trading unused seasonal allocations when the market price of seasonal allocations exceed the utility supply charges. Rents can accrue during a season as irrigators hold unused seasonal allocation and other sources of water become scarce. Prices in the southern Murray–Darling Basin for seasonal allocations rose significantly during the recent drought, for example, and traded well above utility charges. At other times rents may be zero or even negative during flood periods or after harvests, for example, when utility charges may exceed the marginal value and traded price of water.

The trade of seasonal allocations has grown substantially in the past decade, partially reflecting changes to water property right regimes, which have separated the water right from the irrigators land title (Tisdell, Ward and Grudzinski 2001). Goulburn-Murray Water, for example, recorded total traded volumes for the district of less than 40 gigalitres annually between 1989-90 and 1993-94 (when the water reforms were enacted), while trades in 2001-02 exceeded 250 gigalitres (Bjornlund 2003).

Market prices for seasonal allocations vary spatially between irrigation districts and temporally within and between irrigation seasons. Within a season, prices for allocation trades vary due to (among other things) the effect of weather conditions on demand for water, and the effect on storage levels. For example, reflecting the scarcity of water due to drought conditions in northern Victoria, allocation trade prices in the Greater Goulburn trade region of the Goulburn–Murray irrigation scheme reached historic highs of around $500 per megalitre between October 2002 and January 2003 (figure A.1).

Figure A.1 **Pool price of allocations traded in the Goulburn–Murray irrigation district[a], 2000-01 to 2004-05[b]**



a 1a and 1b Greater Goulburn Trading zones. **b** Gaps in time series indicates periods of no trade (primarily between irrigation seasons).

Sources: Peterson et al. 2004; Watermove database.

Trade in entitlements

The majority of the net trade in entitlements tends to occur within, rather than between, trading areas (DNRE 2001; Bjornlund 2003. For example, in Victoria, the volume of entitlements traded has increased gradually since trading commenced in

1990, although it remains significantly less than the volume of trade in allocations. Between 1990-91 and 2000-01, a volume equal to 6 per cent of the total entitlement of farmers in Victoria was permanently transferred.

Administrative restrictions explicitly limit the trade of entitlements between regions and across State borders in the southern Murray–Darling Basin. For example, water authorities in Victoria can refuse ‘out of area’ transfers of entitlements if annual net transfers out of an area exceed two per cent of water rights in that area, this is proposed to be increased to four per cent for all irrigation districts in the southern Murray–Darling Basin by 1 July 2006 (DSE 2006).

These restrictions are likely to alter as utilities across the southern Murray–Darling Basin seek to establish exit fees for transfers of entitlements outside of their service area.

Due to the relatively thin market and confidential nature of many of the trades of entitlements, there is little publicly available information about the prices being paid for entitlements. However, the former Victorian Department of Natural Resources and the Environment (DNRE 2001) noted that the trend in prices has been generally upward. In 1994, 12 000 megalitres of Sunraysia water was sold at auction for about $440 per megalitre, mainly to Sunraysia buyers. By 1998-99, prices of over $800 per megalitre were paid in the Goulburn–Murray region (reflecting, among other factors, drought and the setting of the 1994 Cap on the volume of water that could be taken from the river systems in the Murray–Darling Basin). In 1999-00, Sunraysia prices reached $1000 per megalitre.

Some information on trade in entitlements is also available from the Murray–Darling Basin Commission’s Pilot Interstate Trading Water Project, which has been in operation since 1998. Although the volumes represented by the scheme are quite low — about 19 gigalitres of total trade between September 1998 and February 2004 — it is possible to observe traded prices for entitlements in several regions. Young, Dyer and Thoms (2001) indicate that, through the scheme, entitlements have traded at prices around $500 per megalitre in the Riverland (South Australia), $730 to $1000 per megalitre in Sunraysia, and $1000 per megalitre in New South Wales.

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