There has been increasing awareness that irrigation affects water quality and imposes externalities on downstream users. If these issues are not embodied into the institutional arrangements that govern trade, water markets will not deliver an efficient outcome. Policy makers have a range of economic instruments to address this problem. These approaches can be broadly classified into quantity based instruments, such as a salinity credits, and price based instruments, such a subsidies and taxes on water trade between regions.

In the case where water availability is variable and demand is constant, a fixed tax or a fixed quantity restriction are equally efficient instruments for addressing a market failure with a homogeneous externality. In the case where demand is variable, a fixed tax may still be an efficient instrument but a fixed quantity restriction will impose losses if demand increases. However, owners of water entitlements may still tend to favor quantity restrictions over a tax if the tax imposes greater reductions in the value of entitlements.

To address site-specific differences in the externalities associated with irrigation, it is necessary to maintain or re-establish the link between water use and the land. This could be achieved through water use rights that could be traded independently of water entitlements. These instruments would need to be bi-lateral, reflecting the difference in the external costs of irrigation between the source and destination of the trade.
Introduction
In the mid-1990s the Council of Australian Governments recommended a number of water reforms including a cap on water use, the development of water property rights and the establishment of markets for water trading. In 1995, a cap was imposed on the volume of water that could be diverted from the rivers for consumptive uses in the Murray Darling Basin. While this cap limits further increases in water diversions, it does not constrain new developments provided their water requirements are met by using current allocations more efficiently or by purchasing water from existing developments. Seven years on, there has been only limited progress in defining and allocating well defined property rights and establishing institutional arrangements to promote economically efficient water trade.

At the time the cap was imposed storage capacity and delivery infrastructure, as opposed to water, were scarce resources. Much of the existing infrastructure was funded through public investment intended to increase exports and move people back to rural Australia. It continues to support a large amount of low returning irrigated activities with low rates of irrigation efficiency. While the cap on diversions has effectively made water a limited resource, there has been little pressure for trade to occur. Investments in new, higher returning activities were, and are needed to create the demand to shift water out of lower valued production alternatives. Well-defined and secure property rights are essential to support the level of investment required to gain the maximum return from consumptive water use. Even with the establishment of well defined property rights, investments in higher returning irrigation activities and associated changes in the demand for water are likely to occur slowly. Investments in irrigation infrastructure are largely irreversible and with a large number of sunk investments in place, water supplies are likely to remain inelastic and as a result trade in entitlements will remain thin.

However, this situation may to change with increasing community demands for water to generate environmental services. The Murray Darling Basin Commission has set out potential reductions in irrigation entitlements ranging from 5 to 15 per cent to service environmental demands as reference points for community discussion. As water becomes a more scarce resource in the Murray Darling Basin, the need to establish an efficient water market will become increasing important.

At the same time, there are significant water quality issues associated with irrigation in the Murray River system, in particular river salinity. A salinity audit, released by the Murray Darling Ministerial Council in 1999, projected that salt mobilisation in the basin would double from 5 million tonnes a year in 1998 to 10 million tonnes in 2100. The audit also reported that the average salinity of the Murray River at Morgan, upstream of the major offtakes of water to Adelaide, will exceed the 800 EC World Health
Organisation threshold for desirable drinking water quality in the next fifty to one hundred years (MDBMC 1999).

In the Murray River, the major source of salinity is discharge from irrigation areas that have highly saline groundwater. If impacts of saline discharge are not embodied into the institutional arrangements that govern trade, water markets will not deliver an efficient outcome. The fact that the level of salt discharged from irrigation areas and its impact downstream varies significantly within the Murray River system, means that water trade can have both positive and adverse affects on water quality, depending on the source and destination of the water traded. In redefining water rights to allow trade, allocations were separated from the land to which they were initially assigned. However, to account for the site specific nature of the impacts of trade on water quality requires a link between the location from which the water is sourced and its destination.

Policy makers have at their disposal a number of policy instruments that could be used to correct the externalities arising from water use and trade. Quantity based instruments include trade in pollution credits or permits that are currently being considered in the Murray Darling Basin in the form of salt credit schemes. A second option is to introduce price based instruments through the introduction of site-specific water use rights. The potential advantages and disadvantages of these two approaches is examined in this paper.

**Externalities and water use**

To address the issue of the externalities associated with irrigation and other consumptive water uses, it is important to consider the value of water as both a productive and environmental asset. From a water availability perspective, two of the most important characteristics are that the current supply of water is finite and future supplies are uncertain. Seasonal conditions contribute to the variability of water demand as well.

It is also important to consider how the downstream impacts of water uses, such as irrigation, vary. As noted, there is considerable spatial variation. Differences in ground water salinity, soil types and irrigation practices all influence the impact of irrigation on water quality. The further upstream an adverse impact on water quality occurs, the greater the damage as a greater number of productive and environmental assets will be affected.
Working definitions

To facilitate discussion of the use of economic instruments to account for the externalities associated with water use, and, in particular, irrigation, it is useful to provide some working definitions:

• Within a market, the price of water is equal to the opportunity cost of forgoing the last megalitre used.

• Private opportunity cost = marginal revenue of water use – the marginal cost of delivery.

• Full opportunity cost = marginal revenue of water use – the marginal cost of delivery – the marginal external cost of water use.

• Marginal cost of supply = the marginal cost of delivery + the marginal external cost of water use.

Water prices and the value of water

In the absence of any externalities the private and the full opportunity cost are the same and the water market will efficiently allocate water resources, as illustrated in figure 1. The curve MR represents the marginal return to the use of an additional quantity of water on farm. The downward slope of the curve reflects the assumption that as water availability increases, it is applied to successively lower returning uses. Two levels of water availability are shown, q₁ and q₂. At q₁, the marginal return is equal to the delivery charge, dc. With water availability greater than or equal to q₁, water has no scarcity value as, at the margin, the return to water use is less than the cost of delivery; and the market price of water is zero. The return that accrues to land and management at q₁ is the area bounded by ACF. At q₂, water has scarcity value and a market price p₂, equal to the marginal return on farm, v₂, less the delivery charge. The rectangular area, BCED, is the rent that accrues to the owner of the water entitlement. The area bounded by ABD is the return that accrues to land and management. A reduction in water availability that increases the price of water redistributes the returns between the owner and the user of the water resource. The increase in price does not compensate irrigators for the decline in total returns given by the area bounded by DEF.
A nonspatial externality

It is straightforward to introduce a simple homogeneous externality — that is, one that does not vary with availability, demand or location — into the analysis, as shown in figure 2. The level of the negative externality is given by the cost $e$. Again two levels of water availability are shown.

With water availability at $S_1$, the marginal return $v_1$ is greater than the private opportunity cost $(dc)$ but less than the full opportunity cost of water use $(dc + e)$. The optimal level of water use is where the marginal return is equal to the marginal cost of supply, at $q_1^*$. The optimal water use can be achieved by introducing a quantity based restriction such as a quota or pollution permit that restricts water use from $q_1$ to $q_1^*$. Alternatively, a tax, $t^* = e$, could be introduced on top of the delivery charge to equate marginal returns to the marginal cost of supply. Under either a quantity based instrument or a tax, the full opportunity cost and, hence, the market price of water at $q_1^*$ is zero.

With water availability at $S_2$, the marginal return $v_2$ is greater than the marginal cost of supply. Despite the negative externality associated with water use, the optimal level of water use remains $q_2^*$. There is no need for market intervention as any reduction in water use below $q_2^*$ will reduce net revenue. Nevertheless, setting a constant tax at $t^*$ or quantity restriction at $q_1^*$ still leads to an efficient allocation of water even with variation in water availability. At $S_2$, the marginal return $v_2$ is greater than the cost of delivery plus the tax and a quantity constraint at $q_1^*$ is non-binding. Hence, taxes and
quantity constraints are both efficient instruments when there is variability water availability.

However, the choice of instrument does affect the distribution of returns from the use of that allocation. At S₂, a tax of t* would reduce the rent accruing to the water entitlement from the area ACFD to ABED, with a corresponding reduction in the market price. A quantity restriction does not alter the rents that accrue to the owners of the water entitlement.

Figure 2: An externality with variability in water availability.

Shifts in the water demand function can have an impact on the optimal level of market intervention, as seen in figure 3. At MR₁, the marginal return, v₁, is again less than the marginal cost of supply and a tax or quantity restriction is required to reduce water use from q₁ to q₁*. At MR₂, which represents an increase in the demand for water due, for example, to hot and dry weather conditions, the marginal return is greater than the marginal cost of supply. No market intervention is required to achieve the optimal level of water use at q₁. In contrast to the situation where only water availability varies, taxes and quantity restrictions are not equivalent instruments in terms of economic efficiency when there is variability in demand.
Setting a fixed tax at \( t^* \) does not affect the efficiency of the market allocation when demand varies. When demand is equal to or below MR\(_1\), for example, MR3, the tax generates an optimal level of water use at \( q_3^* \). Here, the tax reduces the returns to land and management as opposed to the ownership of the water entitlement. At demand levels greater than MR\(_1\), the marginal return is greater than the marginal cost of supply and the tax does not affect the optimal market allocation. The tax does reduce the market price of water and the rents that accrue to owners of the water entitlements.

Figure 3 An externality with variability in water demand.

A fixed quantity restriction does not always lead to an efficient water allocation when demand varies. Consider, for example, a restriction that constrains water use to \( q_2 \). At MR\(_1\) this restriction is optimal and a levels of demand below MR\(_1\) the constraint is non-binding. However, at MR\(_2\) the restriction reduces the level of water use below the optimal level \( q_1 \), generating a deadweight loss (the area bounded by the curve and ABCD). There is a corresponding reduction in returns to both the owners of the water entitlement and to land and management. However, the reduction in returns to the owners of the entitlement may not be as great as under an optimal tax (the rectangular areas EBCD and FGCH respectively). Hence, owners of the water entitlement may prefer the use of an inefficient quantity based instrument.
Summary points

The presence of a negative externality associated with water use does not necessarily imply that a water market will fail; it depends on whether the marginal return is greater than the full marginal cost of supply. To address a market failure resulting from a homogeneous negative externality, a tax can be levied on top of the delivery charge or a quantity restriction may be imposed. Quantity restrictions can be direct, in the form of a quota, or indirect. Indirect instruments include pollution permits or credits, such as a salinity credit.

In the case where water availability is variable and demand is constant, a fixed tax or a fixed quantity restriction are equally efficient instruments for addressing a market failure with a homogeneous externality. Owners of water entitlements may favor quantity restrictions over a tax, as a tax will impose greater reductions on the value of entitlements. Where demand is variable, a fixed tax may still be an efficient instrument but a fixed quantity restriction will impose losses if demand increases. Setting appropriate quantity based restrictions that vary demand can lead to an efficient allocation of water resources, but the transactions costs of such a policy are likely to be high. Nevertheless, owners of water entitlements may still tend to favor quantity restrictions over a tax if the tax imposes greater reductions in the value of entitlements. This will be more likely if the owners of the entitlement sell or lease their entitlement rather than use it themselves.

Spatial externalities and water trade

Return flows from irrigation can impose significant downstream costs. Return flows consist of surface runoff from flood irrigation, irrigation drainage and ground water discharge from irrigation areas that reach the river system. Water trade affects return flows that, in turn, affect the quantity and quality of water used downstream. The impact of return flows on water quality is location specific. The extent to which return flows affect water quality depends on several factors, including ground water recharge rates and the ground water salinity underlying the irrigation areas. For example, return flows from irrigation areas with relatively low underlying ground water salt concentrations may provide dilution flows downstream. In that case, a reduction in return flows from upstream irrigation areas may increase the salinity of water supplies downstream, imposing costs on downstream users. Conversely, a reduction in return flows from an area with high groundwater salinity may generate a substantial improvement in water quality and net benefits to downstream users (Heaney and Beare 2001).

Water trade may have an impact on water quality. For example, trade that moves water from an irrigation area with relatively low recharge rates and low ground water salinity
to a downstream irrigation area with high recharge rates and high ground water salinity can produce a series of impacts on water quality. Immediately downstream of the seller, the transfer may increase stream flows and reduce river salt concentration. However, as recharge rates are higher in the downstream area, surface runoff will be lower, reducing the volume of return flows available downstream of the buyer. Further, as ground water salinity is higher downstream, salt concentrations will be increased as more salt is transported to the river system.

The downstream impacts of changes in water quality also depend on the location of the source of that change. Generally, upstream irrigators will affect a greater number of assets than downstream irrigators and, hence, have a higher marginal return from the same level of abatement. In addition, downstream impacts will vary from location to location due, for example, to differing salt tolerance of irrigated crops or differing industrial uses. The benefits of a reduction in salinity need to be accounted for in terms of a specific set of downstream sites affected by the change.

Externalities associated with site specific sources and impacts of effluent discharge have received considerable attention in the economic literature on pollution abatement (Montgomery 1972; Atkinson and Tietenberg 1987; Malik, Letson and Crutchfield 1993). Considering the problem in this context helps to illustrate the need to develop appropriate institutional arrangements to achieve efficient allocation of water. One option is to introduce site specific taxes to account for the external costs imposed on downstream users from that site. Market based instruments such as emissions permits are another option.

In considering emissions permits, Montgomery (1972) established that a separate property right must be defined in terms of the damages generated from a specific source at each affected site downstream to achieve an economically efficient outcome. However, a market solution based on a set of site specific (spatially differentiated) tradable property rights, faces three problems. First, downstream benefits are nonappropriable (the right is nonexclusive). If an individual cannot capture all the benefits of an upstream investment in irrigation efficiency, private markets can not function efficiently (Hartwick and Olewiler 1986). Second, there is considerable uncertainty associated with the level and timing of impacts of an upstream investment in improved irrigation efficiency. When individuals lack information on how upstream activities affect downstream users, a market may not operate efficiently (Hartwick and Olewiler 1986). Third, several authors have noted that while a system of traded spatially differentiated property rights may be a first best policy in theory, the potential complexity and costs of transactions means that it is not practical to implement (Atkinson and Tietenberg 1987; Stavins 1995; Hanley, Shogren and White 1997).
Given the complications associated with implementing spatially differentiated schemes, a partially differentiated scheme may be an effective second best solution. An example may be allowing trade in salinity mitigation credits or water use rights between irrigation areas as opposed to individual irrigators. Trading arrangements may be supplemented by administered restrictions such as ‘trading ratios’ or ‘exchange rates’ between irrigation areas (Malik, Letson and Crutchfield 1993). However, the potential benefits from any specific intervention will depend on the physical and economic characteristics of the problem.

**An example with two regions**

Consider water trade from a region with relatively low marginal returns that imposes a relatively low level of external costs on downstream users (Region 1) to an area with higher returns and a greater external impact (Region 2), as shown in figure 4. The respective water allocations to each region are \( A_1 \) and \( A_2 \). Regional demands are given by the marginal return curves, \( MR_1 \) and \( MR_2 \). The external costs per unit of water used are \( e_1 < e_2 \). The excess supply curve \( ES_1 \) shows the quantity that Region 1 would be willing to transfer to Region 2 at different prices (ignoring differences in transmission losses).

Without market intervention, the quantity, \( q_1 \), is traded from Region 1 to Region 2 at a price \( p_1 \). The full marginal cost of trade, \( MC_1 \), is equal to the trade price plus the difference in per unit costs, \( p_1 + e_2 - e_1 \), which is greater than the marginal return. Imposing a tax equal to the difference in the external costs (\( e_2 - e_1 \)) equates the marginal cost of trade, \( MC_2 \), with the marginal return; resulting in an optimal level of trade \( q_2^* \), at a market price \( p_2 \). A quantity restriction limiting trade to a maximum of \( q_2^* \) would have an equivalent effect, subject to the provisions on the variability of water availability and demand considered previously.

Trade from a high impact to a low impact area is shown in figure 5. Here it is assumed that the external cost \( e_1 \) is greater than \( e_2 \). Without market intervention, the marginal cost of trade, \( MC_1 \), is less than the marginal return, \( p_1 \). A trade subsidy, \( s^* \), equates the marginal cost of trade with the marginal return, yielding an optimal trade quantity, \( q_2^* \). The equivalent quantity based instrument is a minimum trade requirement, increasing the trade from \( q_1 \) to \( q_2^* \), as opposed to a maximum trade volume.

**Site specific water use rights**

As the optimal level of a tax or quantity restriction depends on the difference in the external costs between regions, trades between irrigation regions must be considered on
a bilateral basis if an efficient outcome is to be achieved. As water entitlements are not necessarily tied to the location where water is used, neither temporary nor permanent
trade in entitlements will be able to efficiently address the impact of trade on water quality.

One option is to consider trade in site-specific water use rights. A water use right allows the holder to actually apply a specified volume of water at a location. With well defined trade in water use rights, an appropriate set of bilateral taxes and subsidies on trade can minimise the negative externalities associated with water use and achieve an optimal regional allocation. However, bilateral trade can present large transactions costs as buyers and sellers need to negotiate directly. Defining use rights at a regional level may reduce this problem but there is likely to be a tradeoff between accounting for site-specific damages and establishing a market with a sufficient volume of trade to operate effectively. Further, defining and endowing water use rights is not a costless exercise.

If water use rights are defined in terms of fixed quantities, variability in water demand can, again, lead to an inefficient water allocation. Attempting to define use rights as an average application level, subject to a set of accountable under and overruns, is also problematic. An average use entitlement is not a well defined property right for annual trade as there is no inherent liability or gain from using more or less than the average entitlement. An option to avoid these problems is to define use rights in terms of a share of available supplies. Historical records are commonly used to endow use or access rights to existing users. However, issues such as data quality and the choice of an accounting period leave the process open ended. Alternatively, the government on behalf of the general public can auction these rights. In any case, endowing these rights is likely to attract special interest or rent seeking activities.

**Summary points**

Accounting for site specific differences in the external cost of water use in water trade has significant implications for the institutional arrangements that govern water trade. Taxes and subsidies on quantities trade can, in the example considered, generate an efficient allocation of water resources. However, optimal tax and subsidy rates vary with both the source and destination of trade, which implies that trading arrangements need to be bi-lateral in nature.

As water allocation is not necessarily tied to the site at which water is used, market intervention in the trade of either temporary or permanent water entitlements is unlikely to lead to an efficient allocation of water resources. Establishing site specific tradable water use rights between regions may be one means of improving water allocation when there are site specific differences in the external costs of water use.
Concluding comments

To address site-specific differences in the externalities associated with irrigation it is necessary to maintain or re-establish the link between water use and the land. This could be achieved through water use rights that could be traded independently of water entitlements. Trade between regions can be subject to either quantitative restrictions, a system of taxes and subsidies (or an equivalent set of exchange rates). With both variability in demand and supply, price based instruments have the potential to be more economically efficient that quantity based instruments. In either case, these instruments would need to be bilateral, reflecting the difference in the external costs of irrigation between the source and destination of the trade.

Given the introduction of well defined and secure water use rights, the introduction of either price or quantity instruments to account for the external impacts irrigation will create incentives for new investments in irrigation in low impact regions. However, these investments are likely to occur slowly due to the irreversible nature of investments in irrigation infrastructure. Trade will tend to occur as existing investments come close to the end of their effective life. Nevertheless, having the right incentives in place will speed the adjustment process.

References


