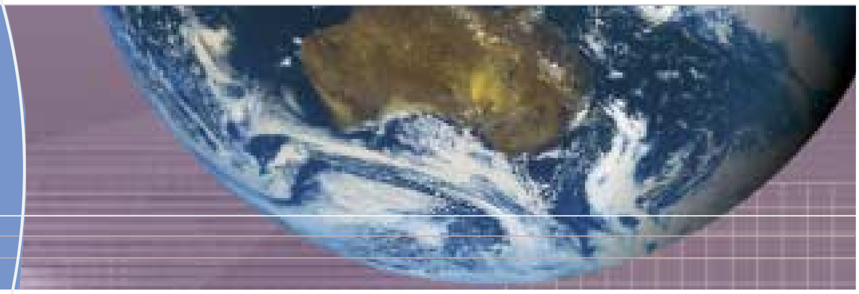
Interim report

Water trade and the externalities of water use in Australia



ABARE paper for Natural Resource Management Business Unit, AFFA

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August 2002

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Beare, S. and Heaney, A. 2002, *Water Trade and the Externalities of Water Use in Australia – Interim Report*, ABARE paper for Natural Resource Management Business Unit, AFFA, Canberra, August.

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ABARE project 2739

Contents

Summary

With the introduction of the cap on irrigation diversions in the Murray Darling Basin, the 1994 COAG commitment to the development of a water trade market assumes higher importance. An efficient water market allows water resources to be used in the highest valued use.

However, there has been increasing awareness that irrigation, and hence water trade, affects water quality and imposes externalities on downstream users. Unless these water quality effects are accounted for, trade will not lead to an efficient allocation of water resources.

Policy makers have at their disposal a number of policy instruments that could be used to correct for the externalities from water use and trade. The objective in this report is to consider the efficiency of price and quantity based instruments in addressing these externalities.

Price based instruments include taxes and subsidies that are used to change the private returns from irrigation to reflect overall social benefits.

Quantity based instruments can also be used to limit water use to the point where additional irrigation would reduce the overall social benefits from water use. 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.

Nonspatial externalities

A nonspatial externality is one that does not vary with availability, demand or location. That is, the effect of irrigation on other water users and the environment is the same regardless of where the irrigation occurs.

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. In the case where water availability is variable and demand is constant, both policies are equally efficient.

However, the imposition of a tax will reduce the market price of water entitlements. This would reduce the market value of one of irrigators' key assets, their water entitlements. It would have a particularly adverse effect on the

income of those who regularly lease their water entitlements to other irrigators. Consequently, owners of water entitlements may tend to favor quantity restrictions over a tax.

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. This is because the fixed quantity restriction is absolute. Irrigation water use above the restricted level is not permitted even though there would be overall social benefits from doing so.

Rather than use a fixed quantity restriction, the quantity based restriction can be varied according to market or seasonal conditions and this, like the fixed tax, can lead to an efficient allocation of water resources. However, the transaction costs of a variable quantity restriction are likely to be high. For this reason, a fixed tax would still be preferred on efficiency criteria.

Notwithstanding the relative efficiency of these two approaches, 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

A spatial externality is one that varies from location to location. Return flows from irrigation consist of surface drainage from irrigation and ground water discharge from irrigation areas that reach the river system. The downstream water quality impact of return flows depends on several factors, including ground water recharge rates and the ground water salinity underlying the irrigation areas. Recent research by Heaney and Beare (2001) highlights how the different combinations of these factors lead to externalities from irrigation that are far from uniform. Consequently, a more practical assessment of price and quantity based instruments must consider spatial externalities.

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.

In the example of water trade between a high impact (large externality) and low impact (smaller externality) region, a fixed price instrument (a tax or a subsidy) is preferred to quantity based restrictions when demand is variable for the same reasons raised in the context of nonspatial externalities.

There are also practical difficulties with a fixed or variable quantity restrictions. For example, it is difficult to imagine enforcing a minimum trading volume from a high impact region to a low impact region.

The fact that the optimal level of a tax or quantity restriction depends on the difference in the external costs between regions implies that 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, changes to the rules for temporary or permanent trade in entitlements will not, on their own, be able to efficiently address the impact of trade on water quality.

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. With well defined trade in water use rights, an appropriate set of bilateral taxes and subsides on trade can minimise the negative externalities associated with water use and achieve an optimal regional allocation.

Defining and allocating water use rights is not likely to be an easy or costless exercise. However, the issues likely to arise have been dealt with in other contexts, such as fisheries, thereby providing the foundation for improved social outcomes.

The analysis in this report provides a useful insight into the institutional reform that could be introduced to address the issue of salinity in the southern Murray Darling Basin. The principles underlying this analysis and the issues likely to arise from the implementation of these reforms need to be discussed if progress is to be made toward implementation.

1. 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. As water becomes a more valued resource in the Murray Darling Basin, the need to establish an efficient water market will become increasingly important. However, there has been increasing awareness that irrigation, and hence, water trade, affects water quality and imposes externalities on downstream users.

The main quality issue in the Murray River system has been increasing 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, South Australia, will exceed the 800 EC[1] 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 ground water. The fact that salt discharges from irrigation areas and that the impacts downstream vary significantly within the Murray River system, means that water trade can have both positive and adverse affects on water quality. Unless these water quality effects are accounted for, trade will not lead to an efficient allocation of water resources.

In redefining water rights to allow trade, allocations were separated from the land to which they were initially assigned. To account for the site specific nature of the impacts of trade on water quality, however, requires a link between the location from which the water is sourced and its destination. One option is to establish trade in pollution permits. This is currently being considered in the Murray Darling Basin in the form of salt credit schemes. A second option is to introduce water use rights. The potential advantages and disadvantages of these two approaches are examined in this paper.

[1] The most widely used method of estimating the salinity concentration of water is by electrical conductivity (EC). To convert 1 EC to mg/L total dissolved salts, a conversion factor of 0.6 generally applies.

2. Externalities and water use

To address the issue of the externalities associated with irrigation and other consumptive water uses, it is important to understand the characteristics 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 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 there are a greater number of productive and environmental assets affected.

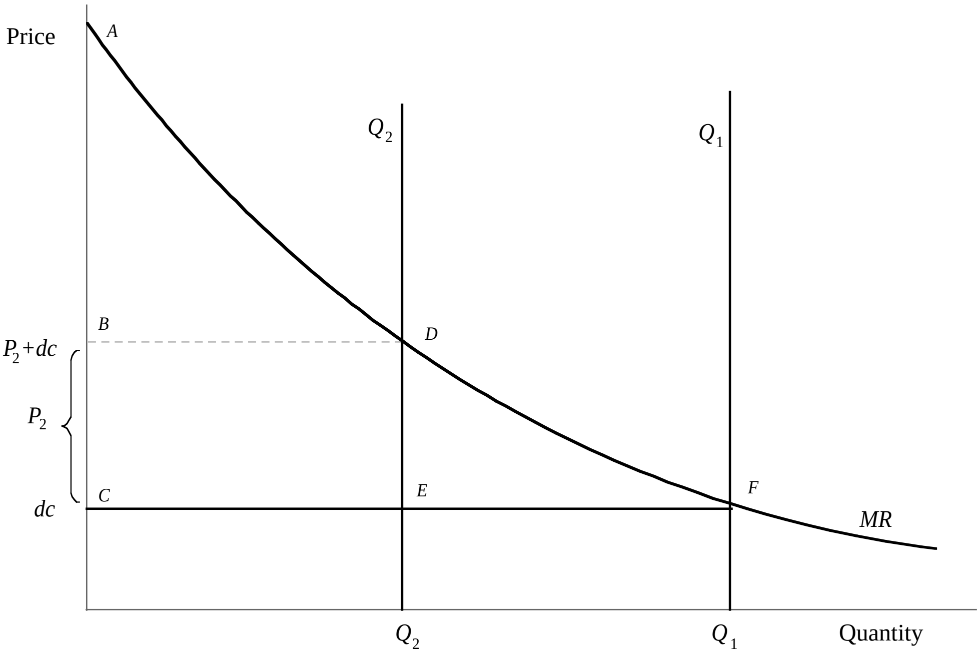
Working definitions

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.

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, Q_1 and Q_2. At Q_1, the marginal return is equal to the delivery charge, *dc*. With water availability greater than or equal to Q_1, water has no scarcity value as,

1 ***Water charges, market prices and returns***



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 under these conditions is the area bounded by *ACF*. At Q_2, water has scarcity value and a market price P_2, equal to the marginal return on farm 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. It in no way compensates for the decline in total returns given by the area bounded by *DEF*.

A nonspatial externality

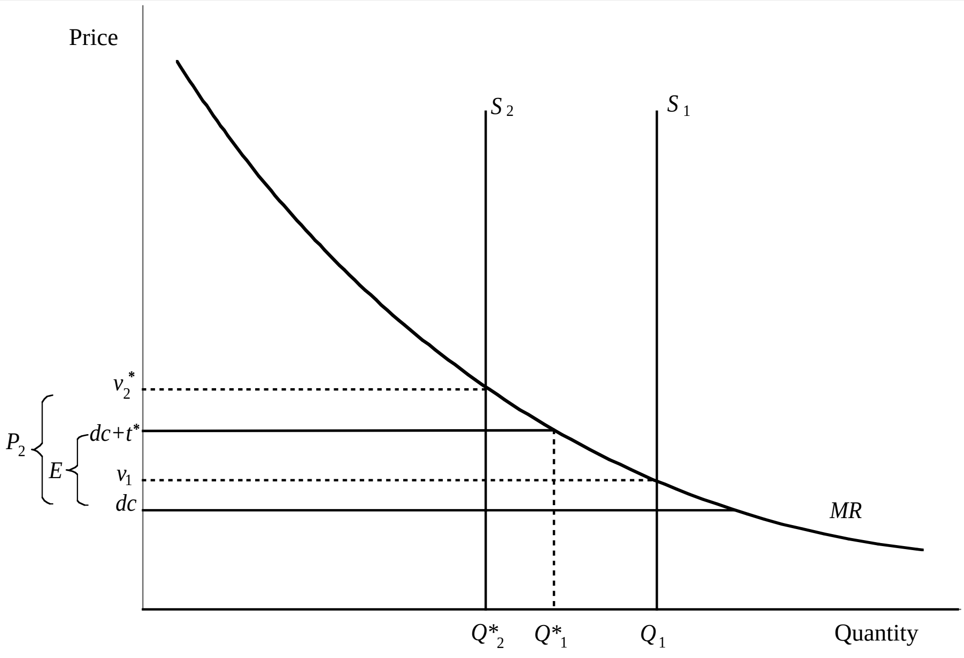
It is straightforward to introduce a simple homogeneous externality — that is, one that does not vary with availability, demand or location — into the analysis, as shown in figure 2. The level of the negative externality is given by the cost *E*. Again two levels of water availability are shown.

With water availability at S_1, the marginal return, v_1 is greater than the private opportunity cost but less than the full opportunity cost of water use. 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 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 revenue by a greater amount than cost.

Although the optimal level of water use will vary with seasonal availability, the optimal level of the tax does not. 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. However, the choice of instrument does affect the distribution of returns from the use of that allocation. A tax levied up to t* will not distort the market allocation at the level of availability given by S_2; the

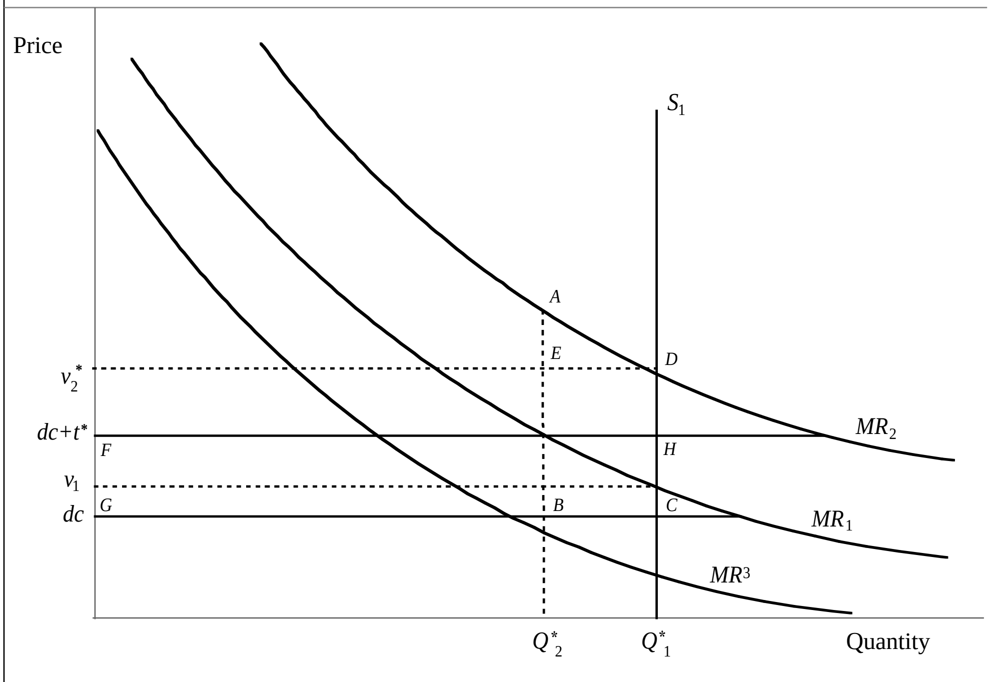
2 ***An externality with variability in water availability***



optimal level of water use remains at Q_2*. At S_2, the tax simply reduces the market price and the rent that accrues to the owners of the water entitlement. A quantity restriction set at Q_1* is nonbinding for any level of availability below Q_1*; hence, at S_2 the quantity used will again be Q_2*. However, there is no reduction in the rents that accrue to the owners of the water entitlement.

Shifts in the water demand function can have an impact on the optimal level of market intervention, as seen in figure 3. At MR_1, the marginal return, v_1, is again less than the marginal cost of supply and a tax or quantity restriction is required to reduce water use to Q_2*. At MR_2, 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 Q_1*. In contrast to the situation where only water availability varies, setting a tax or quantity restriction that is constant over time does not lead to the same outcomes. Setting a fixed tax at t* does not affect the efficiency of the market allocation when demand varies. At demand levels greater than MR_1, the marginal return is always greater than the marginal cost of supply, hence the tax does not affect the optimal market allocation. The tax still reduces the market price of water and the rents that accrue to owners of the water entitlements. At demand levels

3 An externality with variability in water demand



below MR_1, for example, MR_3, the tax remains optimal. The tax, in this case, reduces the returns to land and management.

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 but at MR_2 the restriction generates a loss (the area bounded by the curve and *ABCD*). There is a reduction in returns to both the owners of the water entitlement and to the land and management that use the entitlement. 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). If demand falls to MR_3, the quantity constraint is not binding and the market allocation will be optimal.

Key points

- The presence of a negative externality does not necessarily imply that there is market failure, it depends on whether the market price is greater than the marginal cost of the externality.
- 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 tend to favor quantity restrictions over a tax, as a tax will impose greater reductions on the value of entitlements.
- 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. This will be more likely if the owners of the entitlement sell or lease their entitlement rather than use it themselves.
- Setting quantity based restrictions that vary with conditions that have an impact on demand may lead to an efficient allocation of water resources, but the transactions costs of such a policy are likely to be high.

3. 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 impact of changes in water quality also depends 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 specific 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.

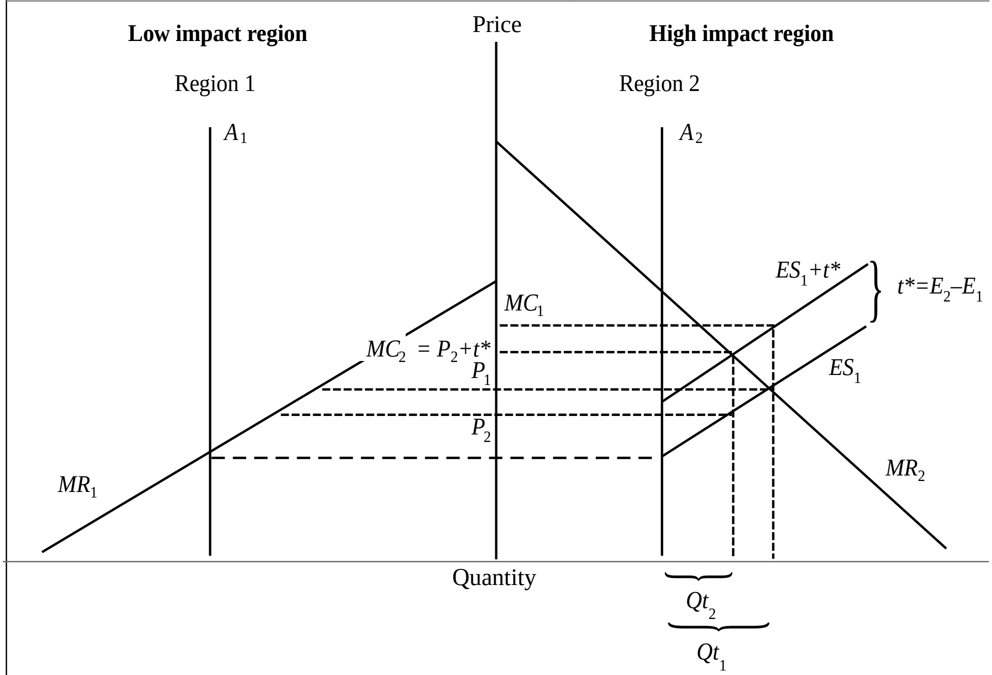
An example with two regions

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 allocation 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 and 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).

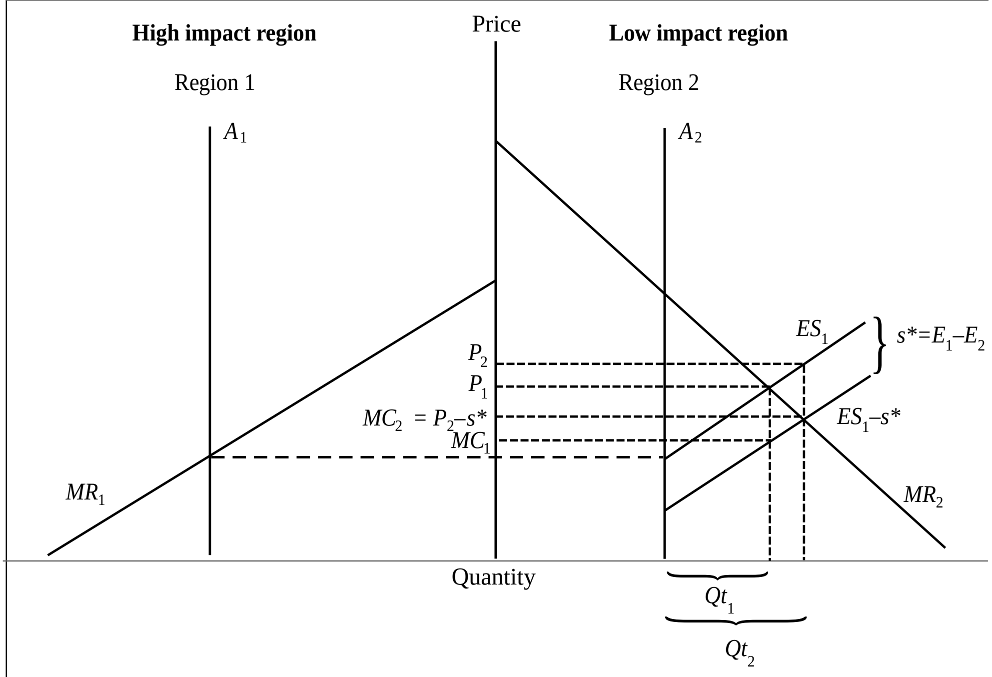
Without market intervention, the quantity, Qt_1, is traded from region 1 to region 2 at a price P_1. The marginal increase in external costs resulting from trade is equal to the quantity traded multiplied by the difference in per unit costs, $E_2 - E_1$. The total marginal cost of trade, MC_1, is equal to the trade price plus the difference in per unit costs, $P_1 + E_2 - E_1$, which is greater than the marginal return (equal to P_1). 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 Qt_2, at a market price P_2. A quantity restriction limiting trade to a maximum of Qt_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, Qt_2. The equivalent quantity based

4 ***Water trade from a low impact region (region 1) to a high impact region (region 2)***



5 Water trade from a high impact region (region 1) to a low impact region (region 2)



instrument is a minimum trade requirement, increasing the trade from Qt_1 to Qt_2, as opposed to a maximum trade volume.

Site specific water use rights

The fact that the optimal level of a tax or quantity restriction depends on the difference in the external costs between regions implies that 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 subsides 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 in 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. However, issues such as data quality and the choice of an accounting period leave the process open ended. As water use rights have financial value, endowing these rights is likely to attract special interest or rent seeking activities.

Key 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. These arrangements need to be bilateral in nature.
- Taxes and subsidies 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.
- 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 entitlement 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.

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