Australian Government
Australian Bureau of Agricultural and Resource Economics

ABARE CONFERENCE PAPER 06.4

Irrigation infrastructure charging:

Non-rival access, cost sharing and exclusion

Stephen Beare, Anna Heaney and Lili Pechey
Australian Bureau of Agricultural and Resource Economics

50th Annual Conference of the
Australian Agricultural and Resource Economics Society
Sydney, February 8–10, 2006

Many irrigation areas are facing the problems of aging infrastructure and a declining revenue base from which to fund maintenance and repair activities. The push toward full cost recovery for storage and delivery services arising from water reform policies means that some supply utilities will need to consider the strategic rationalisation of infrastructure to remain viable in the long term. Consideration must also be given to the implementation of appropriate charging regimes for infrastructure access to ensure that irrigators are not sub-optimally excluded from the delivery system.

Below the point of congestion, non-volumetric charges for access to irrigation infrastructure are analogous to a pricing regime for a non-rival but exclusive good. Two charging models for infrastructure access are analysed in this paper – socialised cost sharing and serial cost sharing – in the context of the efficient provision of a non-rival good. Findings indicate that over-rationalisation may occur under a socialised cost sharing model but that this potential is eliminated under a serial cost sharing model.

ABARE project 3089
ISSN 1447 3666

Introduction

Much of Australia's irrigation infrastructure was built using public funds in the first half of the 20th century. Investment was undertaken on the grounds that it would improve the viability of inland rural communities and enhance the export potential of the agricultural sector. These investments were often made without the intent of recovering the full costs of water storage and delivery services and many of the environmental costs of irrigation were not anticipated. A legacy of this approach to service provision is the socialisation of storage and delivery costs through charges that do not reflect the actual costs incurred. This has led to a reduced capacity to meet full operating and maintenance costs, which in many areas are increasing due to the age of the infrastructure. As part of the broader microeconomic reform agenda in Australia, the 1994 Council of Australian Governments (COAG) Water Policy Agreement sought to address this by requiring signatories to move toward the adoption of full cost recovery principles to support storage and delivery services (COAG 1994). Following the 2004 *National Water Initiative*, rural water authorities are coming under further pressure to reform charges in line with the principles of full cost recovery.

At the same time irrigators continue to face structural adjustment pressures that are reflected in the need to increase productivity. These pressures include declining terms of trade, degradation of the natural resource base resulting from high water tables and salinity, and increasing demand for environmental water and improved water quality. In many regions this pressure has, and will continue to, result in the amalgamation of irrigation farms, cultivation of different crops and the application of new irrigation technologies. This, in turn, results in changes in demand for irrigation storage and delivery services and ultimately determines the need for future investment (or disinvestment) in infrastructure.

Given these pressures, some irrigation regions may need to rationalise their irrigation infrastructure to achieve the objective of full cost recovery. This is particularly the case in those areas that face the twin problems of aging infrastructure and a declining revenue base from which to fund maintenance and repair activity. A charging regime to promote the efficient rationalisation of irrigation infrastructure is presented in this paper. The charging regime is based on a theoretical model that focuses on the non-volumetric component of storage and delivery costs. These costs, in the absence of active constraints on storage and delivery capacity, share the pricing characteristics of a non-rival good or service. Environmental considerations, although important, are not discussed in this paper.

Background

In this paper, attention is focused on irrigation delivery infrastructure. This infrastructure includes channels, regulators and crossings and excludes storage and drainage systems that often work in tandem with the delivery system. For simplicity, a small stand alone component of this infrastructure, known as the ‘lateral spur’ or ‘pod’, is considered. Unlike major and minor channels, no water passes beyond the spur to the rest of the system. While the problem of rationalising a large scale storage and delivery system is more complex, the principles are unchanged.

For the purpose of this paper, public investment in existing infrastructure is regarded as sunk and the capital costs of investment are not considered. The main concern is the two components of the total cost of delivery that must be met by water users: non-volumetric, including recurrent maintenance and repair costs and management costs, and; the volumetric or variable costs of delivery. The former are largely independent of the volume of water delivered and often comprise a substantial proportion of the total cost of delivery.

Historically costs of storage and delivery services were met, in part, by the Federal and state governments. Following the 1994 COAG agreement, irrigation authorities have collected a greater proportion of these costs as they have been privatised or gained greater statutory powers. However, costs have often been ‘socialised’ within irrigation districts. This may occur if, for example, irrigators are charged non-volumetric costs based on the volume of their entitlement, or if these costs are divided equally among all users of the infrastructure as opposed to on the basis of the infrastructure that is being accessed.

In addition to passing on a greater proportion of delivery costs to irrigators, progress toward full cost recovery may also mean rationalising existing delivery infrastructure to ensure the longer term viability of irrigation utilities. In the irrigation context, rationalisation is ‘the strategic decommissioning of infrastructure’ (Moorhouse 1999). The charging regimes in this paper are considered on the basis of facilitating the efficient rationalisation of infrastructure while retaining an optimal number of irrigators within the system.

To be effective, the charging regime should ensure that viable coalitions of irrigators – those that can collectively meet their full non-volumetric service costs – are not excluded from the delivery system that they are accessing. This may require a more flexible approach to recouping non-volumetric costs. For example, it may be possible to collect the full non-volumetric cost of delivery from a subset of irrigators along a lateral spur. At the same time, there may be irrigators along the spur who cannot meet their share of the proposed non-volumetric charges. If, however, they can meet their variable costs of delivery and make a partial contribution to the non-volumetric costs, it may be more efficient to allow them access to the delivery system.

Infrastructure charges

Under Randall's classification system, the appropriate means of provision and charging for a good or service depends on the characteristics of exclusivity and rivalry in the use or consumption of that good or service (Randall 1983). The use of irrigation infrastructure is non-rival (until the point of congestion is reached) and exclusive as an irrigator can be denied access to the delivery system. This implies that the non-volumetric charges are, below the point of congestion, analogous to a pricing regime for a non-rival but exclusive good. A non-volumetric charge that is above an individual irrigator's willingness to pay may lead to the sub-optimal exclusion of that irrigator from the delivery system, though not in all instances.

The problem associated with the provision of non-rival goods is that a non-discriminatory pricing scheme cannot achieve an efficient outcome. (Randall 1983). A single price high enough to generate revenue to cover costs of provision would potentially inefficiently exclude some users who value the good positively and would either result in the provision of less than the efficient amount of the good, or impose additional costs on other users.

Randall discusses the use of discriminatory pricing as this would permit a Lindahl solution which would provide an efficient quantity and price. Under this mechanism, each individual's willingness to pay the non-volumetric charge must be determined. As these costs and the level of access to the service are fixed, the Lindahl price reflects an individuals' willingness to pay their full as opposed to a marginal share of non-volumetric costs. Further, the non-volumetric cost of providing the optimal level of delivery services can be less than the sum of individual irrigators' willingness to pay and pure Lindahl pricing may extract a rent from irrigators. Randall concedes that Lindahl pricing is possible, in principle, but technologically difficult.

Moulin and Shenker (1992) describe an alternative approach to Lindahl pricing that is practical and addresses this problem of overcharging. Their serial cost sharing model is based on work by Littlechild and Owen (1973). The serial cost mechanism takes the following general form: a fixed group of n agents share a one input, one output technology with decreasing returns. These agents can be viewed as members of a coalition. Agent 1 with the lowest demand of output q_1 pays $(1/n)^{th}$ of the cost of nq_1. Agent 2, with the next lowest demand q_2 pays agent 1's cost share plus $1/(n\text{-}1)^{th}$ of the incremental cost from nq_1 to $(n\text{-}1)q_2+q_1$. Agent 3, with the next lowest demand q_3 pays agent 2's cost share, plus $1/(n\text{-}2)^{th}$ of the incremental cost from $(n\text{-}1)q_2 + q_1$ to $(n\text{-}2)q_3+q_2+q_1$.

Moulin (1994) applies this mechanism to the provision of non-rival and excludable public goods such as highways, airports, parks and museums. He found that the possibility of partial exclusion through price discrimination reduces the free rider problem. Moulin also suggests that this 'direct serial mechanism' is 'second best' but Pareto-superior to any mechanism satisfying the four properties: freedom of influence from strategic behaviour within the coalition, anonymity, voluntary participation and non-imposition. The charge is based on the cost of provision as opposed to willingness to pay and, hence, the total charge paid by coalition members is less than or equal to their total willingness to pay. There is no incentive to exclude anyone from the coalition who is able to meet his or her cost share as this would increase the charge faced by those that remain in the coalition. As a consequence, the capacity to form strategic alliances within the coalition to avoid costs appears limited.

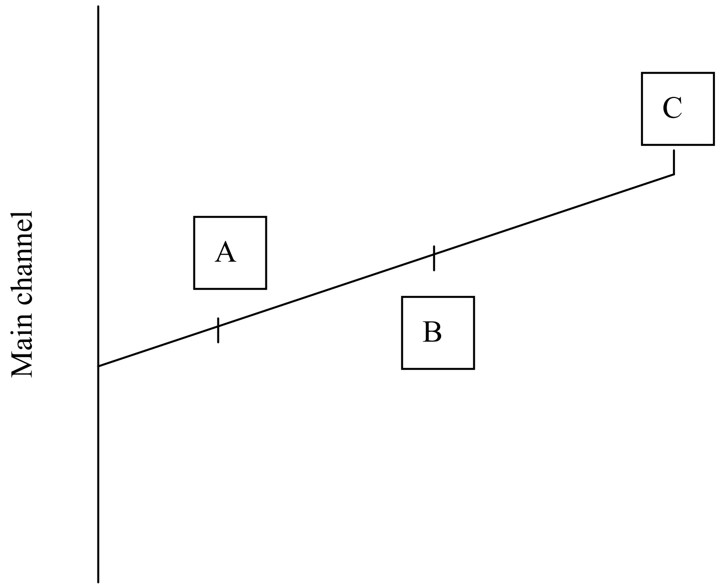
Moulin's approach does not fully address the spatial dimension of irrigation infrastructure rationalisation and the problem of sub-optimal exclusion raised by Randall. If it is economic to provide a delivery service from point A to point B, it may also be economic to provide the service at all points in-between. If the coalition faces no additional costs when it allows an individual to join who can only meet a proportion of their serial cost share, then the coalition is better off if it allows that individual to join. If the coalition were to act as a price discriminating monopolist, it could extract from these potential new entrants their maximum willingness to pay – their Lindahl price. How these fees should be distributed between the original members of the coalition is of interest but is not considered here.

An application to irrigation infrastructure

Consider a hypothetical rural water authority responsible for the management of the lateral spur depicted in figure 1. There are three irrigators that access their irrigation water via this spur: A, B, and C each is located at a successively increasing distance from the main channel. The irrigators are heterogeneous and each has a different willingness to pay for irrigation water. For ease of exposition, it is assumed the capacity of the spur is sufficiently large so that congestion does not occur.

The authority needs to achieve full cost recovery and must increase the charges currently levied. The capital investment is assumed to be sunk, but there are ongoing maintenance and operation expenses. These expenses are both variable and fixed. Variable costs are assumed to depend only on the volume of water delivered. Fixed costs do not depend on how much water is delivered, but they are dependent on the distance from the offtake to the farm gate.

Figure 1: A stylised irrigation spur



The total cost of delivery, TC, is given by:

(1) $$TC = \alpha_A + \alpha_B + \alpha_C + \beta \sum_i q_i$$

where α_i is the non-volumetric cost of delivery to irrigator *i*, β is the volumetric cost and q_i is the volume of water delivered. Consider two charging models, one in which the non-volumetric costs are socialised and the serial cost sharing model.

Under the *socialised charging model*, the total cost of water delivery is apportioned using the following formula:

(2) $$C_i = \frac{\alpha_A + \alpha_B + \alpha_C}{3} + \beta q_i$$

where C_i is the charge to the ith irrigator.

Under a socialised cost sharing model it is possible that over-rationalisation may occur when full cost recovery is pursued. Consider the case where the irrigation authority increases the non-volumetric charges. Suppose the new charge is greater than irrigator A's willingness to pay and he or she elects to exit the industry. Irrigators B and C now face the charge:

(3) $$C_i = \frac{\alpha_A + \alpha_B + \alpha_C}{2} + \beta q_i$$

This concentration of costs is a pecuniary externality and may lead to a case where it is no longer economic for irrigators B and C to operate and the spur may be decommissioned. However, if the irrigation authority accepted a contribution to the non-volumetric cost by irrigator A, up to his or her maximum willingness to pay, it is possible that irrigators B and C may be able to economically make up the balance. In this case it is not optimal to decommission the spur.

The potential for over-rationalisation is eliminated under a *serial cost sharing model* provided all irrigators that can meet their share of costs are able to access the delivery system. The serial cost sharing model takes the form:

(4) $$C_A = \frac{\alpha_A}{3} + \beta q_A$$

$$C_B = \frac{\alpha_A}{3} + \frac{\alpha_B}{2} + \beta q_B$$

$$C_C = \frac{\alpha_A}{3} + \frac{\alpha_B}{2} + \alpha_C + \beta q_C$$

If irrigator A again faces a charge that is greater than his or her willingness to pay and elects to exit the industry, irrigators B and C face the charges:

(5) $$C_B = \frac{\alpha_A + \alpha_B}{2} + \beta q_B$$

$$C_C = \frac{\alpha_A + \alpha_B}{2} + \alpha_C + \beta q_C$$

If irrigators B and C can viably meet these charges the spur is not decommissioned. The spur is not decommissioned if irrigator C can meet the full cost or may be partly decommissioned if irrigator C cannot meet the full non-volumetric cost but irrigator B can meet the full cost of reaching his or her delivery point. If irrigators B and C cannot meet these charges, it is not possible for irrigator A to contribute enough to the non-volumetric costs to keep the spur open on a full cost recovery basis.

However, if irrigators B and C can meet the full cost of delivery, the serial cost sharing model can still lead to the sub-optimal exclusion of some irrigators who can pay their variable costs and make a contribution to the non-volumetric costs up to their willingness to pay for access. Clearly irrigators B and C are better off if A makes a partial contribution and A makes a net contribution to the economy. It should be noted that sub-optimal exclusion can also occur under the socialised cost sharing model.

Concluding comments

In moving toward full cost recovery of water storage and delivery, charging regimes will have an impact on the decision to rationalise irrigation infrastructure. With an inappropriate charging regime, such as socialised cost sharing, viable infrastructure may be decommissioned or fail to be renewed. The serial cost sharing model addresses this problem. However, it can still lead to the sub-optimal exclusion of some irrigators from the delivery system. Irrigators should not be excluded if one, they can cover some part of the non-volumetric cost of storage and delivery and, two, their access to the system does not impose costs on others.

The transaction costs identifying the location specific delivery costs and irrigators' willingness to pay may be significant, especially when there are a large number of irrigators in a given stand alone system. The benefits of doing so will tend to be greatest when there is a relatively high degree of heterogeneity among irrigators and significant differences in their capacity to pay. If everyone has a similar production and cost structure an all in or all out decision is more likely to be an efficient outcome.

The analysis presented in this paper has abstracted from two potentially important issues. The first is congestion. Tradeable access rights are one means of rationing limited delivery capacity and the serial cost sharing model provides a simple model for allocating capacity shares. Shares along a leg of the spur can be allocated according to the proportion of non-volumetric costs paid. If irrigator A is allowed into the coalition, as discussed above, his or her capacity share of the leg from the main channel to first offtake would again be determined by the proportion of non-volumetric costs paid.

The second issue is exit fees. If an irrigator elects to exit the industry and sell their entitlement outside the system, he or she may be liable to pay an exit fee. Clearly this would have an impact on their decision to leave the industry and the subsequent decisions by others as to whether they leave also. This is largely an issue of equity as opposed to efficiency and basing exit fees on the serial cost sharing model would appear to be more equitable than the socialised cost model.

References

COAG (Council of Australian Governments) 1994, Report of the Working Group on Water Resource Policy to the Council of Australian Governments, Canberra.

Littlechild, S.C. and Owen, G. 1973, 'A Simple Expression for the Shapely Value in a Special Case', *Management Science*, vol. 20, no. 3, November.

Moorhouse, I. 1999, 'Asset management of irrigation infrastructure: the approach of Goulburn-Murray Water, Australia', *Irrigation and Drainage Systems*, vol. 13, pp.165-187.

Moulin, H. 1994, 'Serial Cost-Sharing of Excludable Public Goods', *The Review of Economic Studies*, vol. 61, pp.305-325.

Moulin, H. and Shenker, S. 1992, 'Serial Cost Sharing', *Econometrica*, vol. 60, pp.1009-1037.

Randall, A. 1983, 'The Problem of Market Failure', *Natural Resources Journal*, vol. 23, pp.131- 148.