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PRICING FOR IRRIGATION WATER

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PREFACE

This report is part of the work done by the University of Minnesota and Colorado State University for the U.S. Agency for International Development under the Cooperative Agreement for Economic Planning and Policy Analysis for Irrigation. The studies have been concentrated in Asia and North Africa with special emphasis on South India, Northeastern Thailand, Egypt, and Pakistan. The work in Thailand and India is focusing on small scale irrigation while that in Egypt and Pakistan is concerned with large scale projects.

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PRICING FOR IRRIGATION WATER

J. A. Seagraves and K. William Easter

Introduction

This report outlines important factors affecting the choice of pricing systems for irrigation water. It is written for those who have an interest in improving the pricing of irrigation water. First we review the goals of pricing and regulatory schemes and then analyze other factors affecting choices. Marginal cost pricing is explained and identified with a way of thinking about administered prices rather than a rigid system. Finally, alternative pricing schemes are illustrated and some conclusions are offered.

Let us define briefly here at the outset different pricing systems which are used to charge for irrigation water. Four general types can be distinguished: (a) direct charges based on measured volumes, (b) direct charges per share of the flow in a stream or canal, (c) direct charges per acre irrigated, and (d) indirect charges on crop outputs marketed or on other inputs purchased. Volumetric charges are best suited for cases where water has a high value per unit and needs to be allocated efficiently. The major problem with volumetric pricing is the cost of measurement devices required to implement the system. Only if water is highly valued will volumetric measurement be practical.

Pricing water on the basis of shares is effective when water is allocated on the basis of time. Here a farmer is charged for the amount

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of time water flows into his field. The actual amount of water received will depend on the flow in the river or water course which will vary over time.

Charges per acre will have no direct effect on the efficiency with which water is used although it may influence the crops grown and thus indirectly affect water use. Such fixed charges are primarily for the purpose of collecting funds to pay for projects. The same is true for the indirect charges. They are a way to cover operating and maintenance costs and possibly contribute something toward repaying the construction costs of a project.

Goals of Regulatory and Pricing Systems

The main goals of irrigation regulatory and pricing systems are summarized under two broad headings: (1) equity and efficiency. The desire of societies to distribute income equitably often conflicts with the desire to maximize total output or efficiency. Administrators of public water programs often are under pressure to help redistribute income and at the same time to achieve efficient usage of water. The problem is to find a combination of regulations and prices which will accomplish the two objectives. Various subgoals under these two broad headings can be identified.

(1) Equity as it relates to irrigation water encompasses at least three subgoals:

(1a) Recovery of the costs of irrigation from the users. Costs might be recovered so that the money can be reinvested. Other reasons could be to

improve the income distribution or to prevent the transfer of large economic rents.

(1b) Subsidization of food production. This can be done through increasing the prices of products or reducing prices of factors of production such as water.

(1c) Redistribution of income and wealth among groups of farmers, say, from larger to smaller ones.

(2) Efficiency in the allocation of irrigation water has many aspects. The most obvious of these are:

(2a) Allocation of a given amount of water among farms and regions so as to maximize the net contribution to production.

(2b) Provision of signals for optimum investments in new supplies of water and irrigable land, and

(2c) Restriction of excessive use of water by some farmers, which can damage the land of others.

The weights put on these and other goals will differ among members of any society. Farmers may be concerned about the water being efficiently allocated to their fields while politicians will be more interested in seeing that the water gets distributed to as many farmers as possible. Administrators of the irrigation system will want to minimize conflicts between groups and will try to get water to farmers with a minimum of effort.

Economic Efficiency

First, consider the case where the quantity of water available in a given period is fixed. One way to define efficient use of a given quantity of water is to specify that the added benefit per unit of water (or the marginal value product) be the same for all uses. We assume diminishing returns or that additions to each usage, other things equal, eventually will have declining marginal returns. If the marginal benefit is higher for one use than for another, the efficiency of society might be enhanced by permitting some water to be reassigned to the better opportunity. Even though the quantity of water at a given place and time is fixed, a transfer among uses has a "cost," the social value foregone by transferring a unit of water from its next best use, i.e., its opportunity cost. Water should be reallocated among uses until it has the same marginal value product or opportunity costs in each use.

Second, consider the possibility of increasing the water supply. If it is possible to obtain additional water at a long-run marginal cost which is less than its marginal value product, then units of water should be added. Each addition to supply is assumed to cost more than the last (i.e., the marginal cost function is an increasing function of the quantity supplied). It will be argued in the section on marginal cost pricing that new water should be added until the marginal cost equals the marginal benefit.

Finally, Neghassi and Seagraves (1978) stress the difference between physical and economic efficiency. Physical efficiency refers to the ratio of water used by the plants to water diverted. As the value of water increases, it becomes rational (economically) to increase physical

efficiency by adopting improved methods of controlling, measuring, and applying water, and to design better systems of prices which will improve water allocation. Schramm and Gonzales (1976) made one of the few studies that has documented the expected relationship between the method of charging for irrigation water and physical efficiency in its application.

Cost Recovery and Efficiency

The water laws of many countries emphasize that the role of prices is to recover from the users the costs of operation and maintenance and maybe some part of the capital costs of projects. Cost recovery schemes have direct effects on equity and the income distribution, and indirect effects on efficiency. Water laws often specify that government experts will order the efficient use of water. The assumption is that the regulators will know enough to assign to each farm the socially optimal quantity of water. This is not likely to be the case particularly if the poor regulators must deliver water to 50 thousand farmers.

Given the two goals, equity and efficiency, it may be advantageous to use two instruments: regulations (including quotas and permits) and prices (including the possibility of multiple prices, penalties, and rebates). both goals, equity and efficiency, can be incorporated into pricing structures if different quotas are assigned to different groups and similar marginal prices are charged all users. An example of such dual fees is given below in Table 1.

Full cost recovery through prices can contribute to efficient resource use by causing users to stop buying more water when their marginal return

falls below the cost per unit. Also, if users know they will have to pay for a project, they will be more likely to participate in its planning. In some cases that feedback regarding what the water is worth and how much is needed could improve project design. The World Bank encourages full cost recovery or at least recovery of the costs of operation and maintenance from the users. A study of 17 Bank projects revealed that on the average, users were paying back 29 percent of full costs (IBRD, 1974, Table 2). In comparison the users of U.S. federally sponsored irrigation (ASCS, SCS, Bureau of Reclamation and Corps of Engineers) paid, on the average, slightly less than 20 percent of the cost of these projects (Eisel and Wheeler, 1980).

Other Goals

Minimize administrative costs: Decisions regarding water prices and regulations also affect the costs of administration and the likelihood that related political problems will recur in the future. The goal of minimizing the costs of administering resources often conflicts with the goals of efficiency and income redistribution. More efficiency usually involves stricter monitoring, more differentiation of price according to place, time, and quality, and more policing. Adding income redistribution as a goal of water regulations and prices also adds transaction costs. These costs include costs of information, contracting, and policing. Administrators should seek to minimize both the private and the public costs of transactions and problem solving.

Resolving disputes: If farmers cannot buy water at a reasonable price, they will resort to political pressure to correct the situation. One problem could be a shortage of water because the existing price is

set too low and does not allow rationing of the available supply. Many water problems that are basically economic in nature are "solved" with legal decrees or direct government action. Some problems commonly encountered in the development of water resources include: requests for investments without full consideration of benefits and costs; overuse (mining) of ground water; excessive water use causing drainage and salinity problems; pollution, and overuse of streams; large economic rents accruing to a few well placed land owners; lack of system maintenance due to a shortage of funds. The use of economic incentives prices, and transferable permits should be given consideration in solving most of these problems. Economic solutions to these problems might be less costly and more permanent than adopting governmentally specified water allocations.

Factors Affecting Systems for Regulating and Pricing Irrigation Water

Institutions used to allocate water depend on many factors including: the value of the water, dependability of supply, ability to control its flow, desires to subsidize agriculture, traditions of ownership, types and patterns of cropping suited to a specific location, return flows, drainage problems, staff training, delivery systems, information, and the number of farmers involved. No one system of allocation is "best" for all areas.

The Value of Water

If the value to farmers of an additional unit of irrigation water is low, as is often the case, it may not be worthwhile to measure it or levy charges. This would be true even if the cost of the irrigation project

is very high. More accurate measurements and more sophisticated systems for allocating resources tend to emerge the higher the value of the resource. Water pricing schemes, therefore, become more practical when either the cost of measurement and administration is low or the value of the water is high. New technology can reduce measurement costs while greater farmer participation in water distribution can reduce administrative costs.

In addition, just because the value of irrigation water has been low does not mean it will continue to be low. For example, the introduction of HYV's raised the value of water in many parts of Asia and made investments in irrigation improvement very profitable (Easter, 1975 and 1977). It also means that new pricing alternatives should be considered.

Variable Stream Flows

Water may not be priced at its true value because supplies vary a great deal depending on season, time of day, and other factors. If the value of water fluctuates widely, it may be too much trouble administratively to vary the price. Hence, a low price is assigned to encourage full use in periods of abundance, and, then quotas or regulations are used to allocate water among farmers in times of shortage.

When flows are variable, it is common to distribute water among farmers according to shares. Each farm received a certain proportion of the flow of a river for a certain period of time. Fairness may be more important than measured quantities in such circumstances, and farmers may fiercely defend their "right" to a certain share of a river's flow.

The Desire to Subsidize Food Production

Another factor that affects the use of prices to allocate irrigation water is the desire of a government to subsidize agricultural

production. Several reasons may account for these subsidies. If some countries subsidize their agriculture, then it may be necessary for others to do the same simply to compete. Also, farmers affected by large irrigation projects often have little to say in project planning. If a government has non-agricultural purposes for a large irrigation project such as increasing rural employment and national defense, then recovery of full costs from agricultural users may not be reasonable.

Consumers often benefit from investments in agriculture through lower food prices. Since society as a whole benefits, and farmers just go on earning competitive wages, it can be argued that society should pay for irrigation projects. The big losers in this case would be the non-irrigated farmers who gain no increase in productivity but suffer lower produce prices. Related to this consideration is the ability of farmers to pay for irrigation projects. Successful irrigation projects which increase agricultural production a great deal may reduce the incomes of farmers and reduce their ability to pay for those same projects. If those projects are to be used, they may have to be subsidized.

Even though the total social benefits of new irrigation projects exceed the total costs, it may be difficult for governments to recover from users the fixed costs of the installations. One reason is that many irrigation systems are designed so that they will have excess capacity most months of the year. Fixed costs should be recovered only when such facilities are fully used (see section on marginal cost pricing). Since it is difficult to predict such periods and administer the required price flexibility, there is a tendency to recover part of the capital costs from general revenues.

Traditions of Ownership and Water Laws

Water rights and customs pertaining to the distribution of water often have evolved over many centuries. It is necessary to understand the logic behind these traditions before trying to improve them. Three classes of ownership may be distinguished: private property, government ownership and common property rights.

Private property rights over water often evolve as a way of resolving problems. This involves clear definition of one's rights and how they can be transferred. For example, priority water rights are established based on location or year when irrigation started (one group having first claim to a certain quantity). Knowledge of the amount of water they can count on as a "right" or a certainty is crucial to farmers, particularly those with perennial crops. When there is a need to change the ratio of water to land, farmers would be expected to ask the government to establish a system whereby they can transfer water rights separately from the land.

Transferability does not necessarily suggest that owners of large farms will buy all the water, thus taking it away from small farmers. It merely suggests that farmers who are using water more efficiently will be able to bid it away from those who are using it less efficiently. For example, vegetable farmers often have an advantage in such bidding.

Government ownership of water suggests that the state will either: (1) sell scarce water to the highest bidder, or (2) regulate use by establishing crop and irrigation plans. Many water laws decreeing total government ownership also represent a political rejection of the idea of private property and they specifically prohibit all forms of transfer of water among users. This makes it more difficult to manage the water system, especially if the government wants to subsidize irrigation.

Governments often attempt to ration water on the basis of planned or approved crops and the water requirements of each crop. Regulations of this type can be used as incentives to grow crops that are deemed to be in the national interest. Problems often arise in the estimation of individual crop irrigation requirements and in the supervision of individual farm usage. In some countries, government ownership is interpreted to mean "free water" for the farmers who can capture it. This can lead to all the problems associated with open access to resources.

Common property rights mean that the water is owned in common and anyone who is a member of the group can use it as long as they follow the rules of the group. Groundwater resources tend to be common property with very few rules and the water going to those who pump it out first. Lack of ownership or rules restricting pumping leads to a situation where if one farmer does not pump the water his neighbor will. This can cause a rapidly dropping water table and require farmers to deepen their wells continually. Charging for the use of groundwater is one means of reducing its over-exploitation; in fact, in some countries such as Thailand it may be easier to charge for pumped water than it is for surface water. Well spacing and reduced pumping rates have been the most commonly used methods for dealing with declining groundwater tables.

Project Size and Farm Numbers

When the numbers of farmers sharing an irrigation system is small, personal agreements may be used to resolve differences among them. As the number of users and the acres irrigated increases, it becomes more practical to adopt formal procedures to allocate water. A number of procedures have been tried ranging from price rationing to the establishment of fixed allocations per acre.

Ability to Deliver Water and Collect Fees

The combination of regulations and prices used to allocate water also depends on technology and the ability and motivation of the people who run the system. Without appropriate control structures and a trained staff, it is very difficult to deliver water to farmers at the time and in the quantities demanded. If water is not delivered in a timely manner, it may be of little value to farmers and the price they are willing to pay will be low. Uncertainty of water supply also may encourage farmers to use excess water when it is available as insurance against future shortages. This leads to water being wasted and to possible future drainage problems.

A related issue is the ease of collecting the water charge or tax. One of the difficult problems in many developing countries is the ability to collect water charges or taxes. This may be because farmers are unhappy with the way water is delivered or simply because of the lack of any effective collection agency in rural areas. Governments may decide that the easiest and lowest cost (administratively) place to collect fees is in the sale of selected inputs (fertilizers) to farmers or in the purchase of outputs from farmers. For example, the government in Egypt pays farmers a price much below the world price for cotton. The difference is used to finance government projects such as irrigation. Irrigation charges collected in this manner will not influence the farmer's water use on a specific crop. However, by lowering the crop price it can influence the crops grown and indirectly affect water use.

An additional aspect of the collection problem is its effect on income distribution. The larger the irrigated land holding, the greater will be the farmer's benefit from irrigation (assuming the per acre return

is about the same among all size groups). Under most systems of water charges, the large scale land owners will pay the most in total water charges. However, where collections are difficult, there is a tendency for government officials to collect from the politically and economically weaker segments of the population. When this happens, the farmers with the smallest land holdings end up paying their fees while others do not. This tendency causes an even greater disparity in income and has lead a number of people to argue against water charges of any type (Asopa, 1977).

Alternative Systems of Delivery

The methods used to deliver irrigation water affect the pricing systems which are feasible. Three methods commonly used to deliver irrigation water are: demand, rotation, and continuous flow. Seldom is all of the irrigation water in a country delivered by any one of these methods; rather modifications and combinations of the three are used depending on physical conditions, the value of water, and local conditions.

The demand system involves the delivery of water to the farms at times and in quantities as requested by the water user. It works best where water is metered. In open canal systems, such deliveries require a flexible operation capable of matching daily supply with demands. As the name "demand system" suggests, users are able to request the quantity of water they wish and actually get it. Prices based on measured volumes are feasible. This does not suggest that the same price must apply to the whole volume purchased by one user; quotas at low prices plus penalties for exceeding them, or gradually increasing block rates, and declining block rates are all feasible. Farmers might

also pay a capacity charge for their share of the system's capacity plus a volume charge on the metered water.

With the rotation system, water is delivered to the users along a canal in turns according to some prearranged schedule. A fixed schedule makes it difficult for farmers to delay receipt of their water or to transfer it to someone else along a different canal. A flexible schedule, however, would also cause problems, by making it necessary to inform users of changes in the time of arrival of the water at their farms.

The most practical way to charge farmers on a rotation system may be by the number of shares or the proportion of the water they receive. This ties the cost of water to usage, which is desirable if water is valuable. Sometimes shares are converted to estimated volumes per hectare and farmers are charged for the cubic meters they are estimated to have received. Often they are charged according to hectares served or hectares of each crop times an estimated volume of water for that crop; this simply means that the water charge is a land tax or a differential land tax for different crops.

Under the continuous flow system, water flows continually through a canal and each farmer is free to take whatever quantity reaches his fields. However, the flow tends to vary throughout the system and the quantities received depend on location in the command area. In some systems water flows continuously in the canals throughout the cropping season. The water itself may have little value at the margin even though the delivery system may be costly. In such cases, farmers usually pay annual fees for access to the water or contribute labor toward the maintenance of the canal. It is not practical to estimate the amount of

water used or to charge different amounts per hectare for different crops. It might be reasonable, however, to levy charges per hectare and to vary these charges seasonally or by location in the delivery system depending on the cost of storage and delivery or the value of water. Numerous studies have shown that water availability decreases as one moved down canals towards the end of the delivery system (Bromley, et.al., 1980; Wolfe, et.al., 1979; Wickham and Vatera, 1979; Tabbal and Wickham, 1977).

Return Flow and Drainage

Pricing or regulatory systems selected for irrigation may have to be adjusted because of secondary effects such as the reuse of water downstream and possible drainage problems. Only part of the water delivered evaporates or is absorbed by crops. The rest is returned on or through the ground to some water course or aquifer where, if its quality permits, it may be used again. When a second diversion of the water is made, the same situation is repeated with the diminished quantity (and quality) of water (Howe and Easter, 1971, p. 24).

Drainage problems have the opposite effect. Water not evaporated or absorbed by the crops may accumulate in the ground and raise the water table or flood low areas and cause crop damage and salt accumulation.

Secondary effects on other property owners, or "externalities," often go unnoticed. However, when they are important, one would expect them to affect water regulations and prices. Positive externalities, such as useful return flows, mean that irrigation water has a higher social value than the price that the farmer pays. Negative side effects, such as drainage problems, usually suggest restrictions on wasteful usage upstream, pollution taxes, or raising the price to include social costs.

Marginal Cost Pricing

Economists tend to recommend marginal cost pricing systems which will contribute to efficient use of resources and which, incidentally, resemble the system of prices which emerge under competition.[1/] However, in the real world of administered prices, it is rare that one encounters any reference to economic efficiency as a goal. Administrators must respond to other pressures, such as conflicting demands by special interest groups on the one hand, and demands that pricing be "fair" on the other. Administrators rarely are criticized for setting prices too low or in such a manner that contributes to inefficient use of resources. Seasonal price variations are usually avoided even though they might be useful as a long-run solution to a problem. Simple rules are adopted for estimating average costs or "fair" prices. Before attempting to explain the efficiency of marginal cost pricing, we will define it in three simple situations and explain it in a dynamic setting.

Three Simple Situations

An easy situation in which to apply the principle of marginal cost pricing is one in which demand is expanding, present facilities are used year round, and new facilities are being added. Then, long-run marginal cost, LRMC, is recommended as the price. The best estimate of LRMC would be the average total cost of water from the most efficient new project.

[1/] There are many good descriptions of marginal cost pricing and problems with it. Articles by Milliman (1972) and Coase (1970) merit special attention.

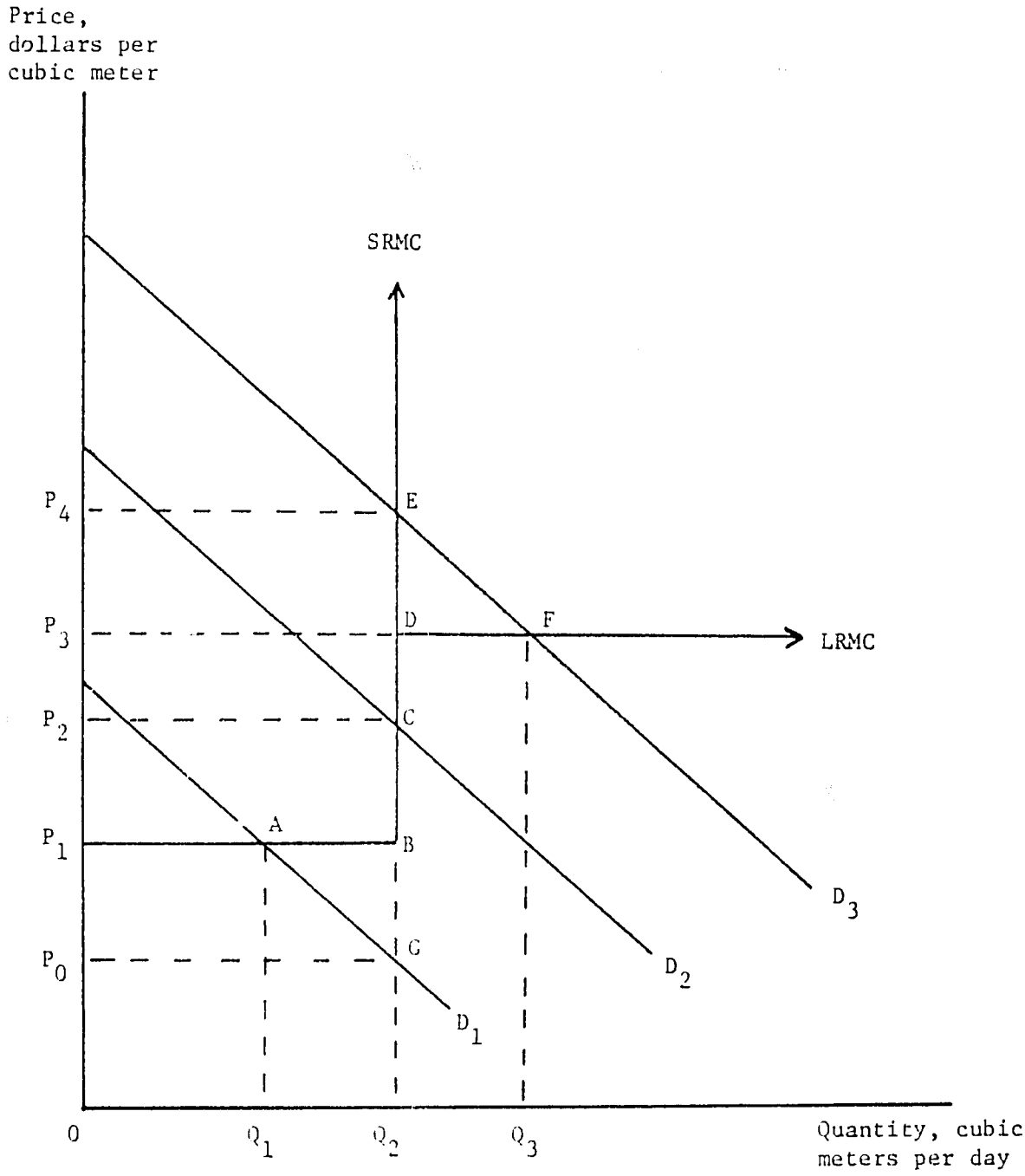
A second situation is one in which new facilities are used only part of the year and must be expanded to meet a peak demand. Marginal costs in the peak period would include all the fixed costs of the new facilities and the operating costs. Off-peak marginal costs and prices should reflect only the operating costs of offering additional service in those slack periods. These simple rules often cause economists to recommend extremely high prices in peak periods and very low or zero prices for the slack periods. The shorter the period of peak usage the greater the disparity.

In a third situation there is excess capacity year round. The main component in marginal cost is the operating cost of providing water. Since the cost of the fixed facilities are sunk costs, they should be ignored or just the amortized current salvage value included as part of marginal costs. Many administrators simply cannot accept the economist's recommendation to forget past expenditures. Writing off fixed costs is especially difficult if the demand is inelastic. Then the percentage decrease in price is greater than the percentage increase in quantity, and total receipts fall every time price is reduced.

An Illustration of Marginal Cost Pricing

The dynamics of marginal cost pricing are illustrated in Figure 1 where demand expands from D_1 to D_3, and prices are adjusted to equal marginal costs. The short-run marginal cost function, SRMC, is assumed to be constant or flat at a level P_1 until capacity is reached at B, when it becomes vertical. The long-run incremental or marginal cost function, LRMC, is constant or a horizontal line through P_3DF. It

FIGURE 1. Illustrating the dynamics of marginal cost pricing



includes new capital or capacity costs expressed as amortized annual amounts per unit, plus operating costs. If the initial demand is D_1, then the optimum price would be P_1, which would cover only operating costs and allow nothing for capacity costs. Only part of the capacity, OQ_1 of OQ_2, is used at this price. As long as there is excess capacity, the marginal cost pricing rule would not include any charge for capacity. As the demand grows to D_2, it is optimal to raise price to P_2. At this price, operating costs are being covered and there is some contribution toward covering capacity costs (the rectangle P_1BCP_2). As the demand grows, it continues to be optimal to raise price along the vertical segment of the SRMC function until price equals the long-run incremental costs, i.e., until consumers are willing to pay an amount equal to operating costs plus the capital costs of new investments. As demand grows beyond this point, additional investments in capacity should be made. For example, if the demand shifts to D_3, it will be efficient to make an investment in new capacity of Q_2Q_3. During the construction of new facilities, scarce water would be rationed by charging a higher price, OP_4.

Once the new facilities are built and OQ_3 is being produced, the price should fall to P_3, the long-run marginal cost. The social benefit of the additional capacity is represented by the area Q_2EFQ_3, the social cost by Q_2DFQ_3, and the net benefit is the triangle DEF. Although this example is highly simplified, it displays the fundamentals of marginal cost pricing and investment decisions too often ignored by water utilities.

Economic Efficiency and Marginal Cost Pricing

Economic efficiency is achieved when it is not possible to increase the welfare of society by reallocating water to other uses. Two distinct cases can be identified: (1) If the quantity of water is fixed, then the marginal social benefits (MSB) of additional water allocated to each use should be equal. The value of one additional unit of water corresponds to the marginal social benefits in its best alternative usage, which is also the opportunity cost of water. (2) If additional water can be secured at some marginal social cost (MSC), then maximizing social welfare requires that additional water be obtained until the marginal social benefits in each use are equal to one another and equal to the marginal social cost. Efficiency in these two cases can be described algebraically with the expression

$$MSB_1 = MSB_2 = \ldots = MSB_n = MSC.$$

This definition of an optimum state as MSB = MSC does not say how to achieve it. Two extremely different approaches are: (1) Command: Experts can make studies to find allocations that fulfill the condition and then simply command people to allocate these optimum amounts of water to each use. This also is called the "beneficial use" or "social engineering" approach. (2) Markets: Alternatively, society can set prices more or less equal to marginal net social costs (MNSC), which include the costs of producing the water plus all the important social effects (both positive and negative externalities) associated with both production and usage. An example of a positive externality would be useful return flows, whereas salinity problems would be a negative exter-

nality. Net marginal social costs thus are used as a guide in setting prices charged,

$$P \simeq MNSC,$$

and these prices, when paid by the users, become their marginal costs. Individual users acting rationally will keep on using more water until their marginal private benefits (MPB) in each use are roughly equal to price, P,

$$MPB \simeq P.$$

Logically speaking, this market allocation of water would tend to be the same as that prescribed by "social engineers" under the command system.[2/]

These descriptions of marginal cost pricing make it seem like something definite which can clearly be recommended. But, that is not so. In reality, marginal cost pricing appears as a tendency or a way of thinking which shapes any number of small changes in a pricing system. Peak demand or drought supply price rationing schemes are common examples. Other examples might be giving credit for positive externalities and charging for negative ones. These appear as highly individualized trials

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[2/] More precisely, we are saying that there are social effects or externalities on both sides. Those connected with supply could be called the social costs of supply (SC), and those connected with usage could be called social benefits (SB). These externalities are expressed per unit of water produced or consumed and could depend on the level of usage. Net social costs (NSC) per unit are NSC = SC - SB. The marginal social costs are the marginal costs of producing water (MCP) plus the social costs, MSC = MCP + SC. The marginal social benefits of using more water are the marginal private benefit plus the social benefits, MSB = MPB + SB. If the social benefits (return flows) of applying water to different crops differ widely, then the idea of one price for all usages breaks down. That is, the price P = MNSC = MCP + SC - SB should not be the same for each usage if the SB's differ widely.

of slightly more sophisticated pricing schemes, and many times they are tried and found to be defective or too complicated.

The Elasticity of Demand and Marginal Cost Pricing

Marginal cost pricing is more important the more elastic the demand. The elasticity of demand is a measure of the percentage change in quantity associated with a 1 percent increase in price. For example, if a 1 percent increase in price causes a 3 percent decrease in quantity, we say that the elasticity is -3, or highly "elastic". A very low price elasticity, such as -0.3, would mean that setting the price away from the marginal cost has very little effect on quantities used and social welfare.

In the very short run, and at low water prices, the elasticity of demand for water is likely to be low. However, as the water prices rise and the length of run increases, the price elasticity increases. The same percentage changes become more important in absolute terms and, when prices increase, it becomes profitable to consider ways to use it more efficiently. Higher water prices encourage farmers to use better control methods and to shift to crops which use less water. Therefore, as one goes from lower to higher prices, and as one goes from short-run to long-run demand curves, the elasticity will increase[3/] and marginal cost pricing will have a greater impact on water use efficiency.

[3/] Shumway (1973) found that at prices above $8.50 per acre foot for California-Aqueduct water, the price elasticity exceeded -1.0 and reached -2.03 at $17 per acre foot. At $4.00 per acre foot the elasticity dropped to -.48. Shumway's derived demand can be characterized as a long-run demand. In contrast, Moore and Hedges (1963) found in Tulare County, Calif. lower water price elasticities for what was a short-run demand situation. They found price elasticities for irrigation water of -.702 at higher prices and -.188 at lower prices.

Alternative Pricing Schemes to Recover Specific Sum Each Year

It is easy to invent a number of pricing schemes that provide about the same annual revenue. Table 1 illustrates five systems that were proposed in a study of water pricing alternatives for a small Peruvian valley. The first, a flat fee for the whole valley is simple and easy to administer. It would help new farmers in the newly irrigated areas get established but it would be somewhat unfair to those in the old valley because they will be paying part of the costs of the new irrigation system.

The second system only charges the farmers in the old section the cost of their existing system, i.e., \$.60/1000 m^3 for variable costs and \$.02 for unrecovered fixed costs of existing facilities. All of the cost of the new facilities for irrigation water would be borne by the new users. Those who benefit pay.

Separate fees for each season could be calculated by different methods depending on how much emphasis is placed on water conservation during the season in which water has a high value per unit. These different systems of setting seasonal fees are illustrated in the third section of Table 1. Seasonal fees represent a simple kind of marginal cost pricing. The object is efficiency. Farmers in both sectors of the valley would be paying the same price at any one time. This contributes to efficiency by giving them incentives to equate their marginal benefits of water.

The fourth proposal is a compromise between desires for equity and efficiency. It leaves the old sector paying the same total amount as at present but charges users in both sectors a much higher rate during the period of high water values which encourages conservation.

TABLE 1. Alternative systems of water fees for collecting the same annual sum in Cañete, Peru, $713,380 expressed in 1974 dollars[a].

Systems	Low-valued season	High-valued season
	(dollars per thousand m^3)	
1. A single fee for the whole valley	$1.02	$1.02
2. Separate fees for each sector:[b]		
Old valley	0.62	0.62
New valley	1.24	1.24
3. Separate fees for each season based on:		
a. Zero in low-valued season	0	1.64
b. Fixed costs to high-valued season	0.60	1.28
c. Linear programming proportions[c]	0.20	1.52
4. Separate fees for sectors and seasons:[c]		
Old valley	0.12	0.92
New valley	0.26	1.84
5. Dual fees:		
a. Zero in low-valued season:		
Flat fee for all water	0	0
Additional fee above basic allotment[d]	0	5.58
b. Fixed costs to high-valued season:		
Flat fee for all water	0.60	0.60
Additional fee above basic allotment[e]	0	4.98

[a]Source Seagraves and Ochoa (1978, p. 50).

[b]Linear programming solutions with and without new investments in land and water indicated the following quantities of water. The "difference" was used to calculate average fixed costs for the new sector.

Area	Low-valued season Mar-July	High-valued season Aug-Feb
	(millions of m^3)	
Future, Whole valley	259	437
Present, Old valley	93	157
Difference for new areas	166	280

[c]A linear programming solution for this valley based on the quantity of water exceeded 75 percent of the time indicated that the total value of water in the season of greatest use (August through February) was 92.5 percent of the annual value leaving only 7.5 percent for the period March-July. These proportions were used to allocate costs in systems 3c and 4.

TABLE 1. (continued)

[d]The marginal value of water in the high-valued season from the linear programming solution was $5.58. This was divided into the amount of money that was to be recovered from the users, $713,380 per year, to obtain an estimate of the quantity of water, 127 million m^3/year, that would pay the marginal fee. That was 29 percent of the water programmed for those seven months. Hence, 71 percent or 311 million m^3 was considered basic allotment.

[e]In this system only 59 million m^3 or 13.5 percent of the high valued water would be paying the additional charge of $4.98. This, plus the flat fee of $.60 per 1000 m^3, makes the marginal cost of water to farmers the same $5.58.

The fifth proposal, dual fees, provides the greatest incentive for efficient use of water. The estimated future value of water in the high-values season with new investments in land and water is \$5.58/1000 m^3. If this were applied to the whole quantity of water used in that season, it would provide much more revenue than the target, \$713,330. So, quotas or basic allotments could be created. The basic allotment (71 percent of the water in case 5a) would be free, but any water that farmers want to buy in excess of their quotas would be sold at the estimated value, \$5.58/1000 m^3. In the second proposal, 5b, the variable cost of \$.60/1000 m^3 is charged on all water that is used year round with an additional charge for water above one's basic allotment imposed only during the season when water has a high value. The rationale of quotas and dual fees is to accomplish three objectives: (1) efficiency -- the marginal price reflects the opportunity cost of water, which is the same to all, (2) equity -- the target sum is collected, and (3) freedom -- everyone is free to buy the quantity of water they choose. The efficiency of water use would also be improved by permitting the transfer of basic allotments among farmers or to have the state buy back unneeded quotas and resell them.

It is not necessary to conduct an expensive study in order to adopt a dual pricing scheme. Howitt (1976) proposed using the functional relationship between quantity of water per hectare and the estimated net revenue per hectare to find the intensive margin, or the allocation of water which maximizes net revenue per unit of water. This could be used to establish both the basic allotment per hectare and the marginal price. Alternatively, if there is a target revenue, the basic allotments may need to be adjusted to recover that amount.

Fees Based on Benefits

A common fallacy in the literature on irrigation pricing is a recommendation that prices be based on benefits. This means that the users of the same water supply will have different prices. Benefit pricing is an attempt to recover all or part of the economic rent or surplus generated by the irrigation project. Gardner, et.al. (1974) explain several ways that estimated net benefits can be used to assign different prices to different regions. Net benefits per unit of water provide an upper limit on prices since they reflect the maximum amount a farmer would be willing to pay. Net benefits could be estimated as the difference in net income with and without irrigation. However, this economic rent will vary among farmers and may be difficult to calculate. The inefficiency connected with having widely different prices for the same water can be explained with the aid of Figure 1.

Assume that D_1, D_2, and D_3 are the demand curves of three classes of users, that the horizontal axis represents water per hectare, and that Q_2 represents the same amount of water per hectare being allocated to each class of user. A literal interpretation of the recommendation that each class of user should pay according to its marginal benefits would result in three prices, P_0, P_2, and P_4, a different price for each group. However, economic efficiency could be enhanced by allowing trading among classes of users. The desired result is not that each class should use the same quantity of water per hectare, but that at the margin each individual should obtain the same benefits. All farmers using one irrigation system should pay about the same marginal price in order to make them, as independent agents, choose quantities of water

that equalize their marginal benefits and maximize total project benefits.

Non-price Rationing

In many countries there are shortages of water partly because the price of water is set below its marginal value or opportunity cost. Some system of rationing or assignment of water is needed. Each farmer could be given a share of water based on his irrigated acreage. Water might be made equally scarce to all farmers. This would force each one to allocate it about as well as if it were priced. There also might be some additional water available at its marginal cost or opportunity value. That would amount to the same thing as dual fees and price rationing. Allowing transfer of shares and quotas has the same effect as price rationing although no revenue is collected to pay for the system.

Conclusions

a. Regulations and prices for irrigation water will reflect conflicting goals such as: (1) the need to encourage efficient use of water; (2) the desire to subsidize agriculture versus the desire to recover the costs from users; (3) the desire to favor small farmers; and (4) the need to minimize administrative costs. Different weights are given to these and other goals in different countries. Emphasis has been given here to defining ways in which prices can contribute to efficiency of irrigation systems and, to a lesser extent, to explaining systems of water rights and government pricing which can be used to redistribute income.

b. Institutions which are appropriate for regulating and/or pricing irrigation water depend on a number of factors besides the goals: the value of water, the variability of stream flows, the ability to control and measure the flows, traditions of ownership, staff training, the extent to which excessive usage is a problem, the value of return flows, and the number of farmers.

c. For economic efficiency reasons, it is desirable to base administered prices on the marginal cost of acquiring more water, or on its opportunity cost in alternative uses. However, it is often contended that prices based on marginal costs will be too high. An alternative system of dual fees would use a low initial fee for quotas plus a higher marginal charge for any units of water purchased in excess of one's quota. Economic efficiency will also be increased if quotas are transferable among users, or if the state is prepared to buy and sell unused quotas. Initial assignments or quotas could be based on historic water rights or on a minimal quantity of water per hectare that is thought to maximize net returns per unit of water. The high marginal prices charged for water purchased in excess of one's quota could be based on its value or opportunity cost. The basic idea is that marginal prices need to be flexible so as to ration the available supplies of water. Such dual price systems may be an effective way to improve the use of both surface and groundwater in many countries.

d. Marginal cost pricing of water has special relevance to seasonal shortages and chronic over-irrigation. Extra high prices could be used to ration all of the water and to recover fixed costs during periods of peak demand. In off-peak periods, a low charge that is indepen-

dent of usage might be satisfactory. Charges for water can also contribute to the efficient allocation of water among regions and between farm and nonfarm uses. Systems of dual fees also can be used to give farmers incentives to reduce excessive irrigation. Quotas for minimal amounts of water needed plus penalty charges for exceeding quotas could be used for this purpose. Penalties would be set to reflect the cost of damages created by excessive irrigation such as flooding and salt accumulation.

e. Institutions for the management of water from irrigation canals are affected by the ease with which the flow can be measured. Since volumetric measurements are costly, they are recommended only when the value of water is high. A common fallacy in irrigation literature is the argument that measurement of volumes of water is always desirable and that charges based on volumes are essential to efficient usage.

f. When flows are uncertain, shares rather than volumes of the water can be allocated to individual farms. A proportion of the river is diverted to a canal and a definite share of this uncertain quantity is allocated to each farm. Shares, or the number of minutes that a farmer will receive water, may be known, whereas the volume that will arrive is uncertain. Under such situations, farmers might be permitted to rent or buy shares or minutes of water from one another or from the government. The allocation of water among users could be highly efficient under such a system. That is, all farmers could have approximately the same marginal value for the last share purchased.

g. It is not worthwhile to seek greater physical efficiency in every instance. The irrigation system that is economically most efficient depends on the value of water and other variables. When the value is zero,

it is hardly worthwhile to limit the use of water; however, emphasis might need to be placed on protecting lower lands from excessive water. When the value is high, water can be transported in tubes under pressure and prices can be used to encourage a high level of physical efficiency with sprinkler or drip irrigation systems.

h. Additional studies are needed of the impact of alternative water pricing schemes on water use efficiency, cost recovery and the distribution of income. Very few studies are available to help administrators select the combination of pricing and regulations that best meets their needs.

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