Special Papers

Marginal Opportunity Cost Pricing for Municipal Water Supply

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Abstract

This paper describes the general rationale for marginal opportunity cost (MOC) pricing, illustrating the concept with special reference to municipal water supply. The various elements of MOC for water, namely marginal production or private cost (MPC); marginal user or depletion cost (MUC); and marginal environmental or external cost (MEC) are described and some numerical examples provided. The relevance of border prices in determining the MOC of tradeable commodities is also considered. The paper then reviews some of the key issues involved in actual implementation of MOC pricing. These include the treatment of externalities, measurement, financial and fiscal, income distributional and second best matters. The paper concludes by listing some possible research topics relating to MOC pricing. While the focus of the paper is on estimation and implementation of MOC as applied to municipal water supply, the approach and techniques employed are of general relevance. Other resources, such as coal and forests are referred to when they provide better illustration of some of the generic issues covered in the paper.

A. INTRODUCTION

Economic Efficiency and Marginal Cost Pricing

An important benchmark by which pricing policies may be judged is the contribution those policies make toward economic efficiency. An efficient policy may be defined roughly as one which maximizes the net benefits accruing to a community from a given course of action, with no consideration paid to the way in which those benefits are distributed. A proposition stemming from this definition is that the price of any service or commodity should be equated to the cost of producing an additional unit of it, or in other words, to its marginal or incremental cost. If consumers are willing to pay a price that exceeds marginal cost, it means that they place a value on the marginal unit consumed at least as great as the cost to the rest of society of producing that unit, and output and consumption should therefore be expanded when system capacity is reached. If, on the other hand, the market clearing price is less than marginal cost, it can be assumed that there is oversupply of the commodity, the cost of additional output exceeding the benefits.

Whether or not a policy is thought to contribute toward efficiency will depend upon the community whose benefits the analyst is interested in maximizing. Having determined the relevant target group of people, the marginal cost calculation requires a distinction to be made between purely financial or accounting costs, and the real (or economic) costs incurred by that group. The former costs, which might include repayment of past loans, simply represent a transfer of income within the community. Efficiency in resource allocation dictates that these "sunk costs" be ignored for pricing purposes, for they represent no net loss, or avoidable cost, to society as a whole. On the other hand, the resources employed in the construction and operation of a particular project represent, at the time of employment, real costs in terms of opportunities forgone elsewhere. Similarly, adjustments to financial data need to be made where general price distortions exist. Where necessary, shadow prices representing the true economic cost of resources employed should be used for labour, foreign exchange, and capital, and adjustment made for transfer items, such as indirect taxes and subsidies.

In a perfectly functioning market system, prices would approximate marginal cost. In practice, market distortions frequently require explicit government intervention, which may take the form of public operation or regulation of services such as water supply, or interventions to remedy the consequences of market failure, such as the use of pollution taxes or regulations. As noted, in such circumstances, marginal costs should be estimated and used as a basis for pricing in order to encourage efficient use of the commodity or service concerned. In practice however, whereas market failure may indicate the need for compensatory action on the part of government, the reverse often occurs. Governments frequently provide incentives which encourage environmentally damaging behavior; thus, water and energy subsidies are commonly encountered, particularly in developing countries. The perception that water is a "free good" is commonplace, but as municipal managers throughout the world know only too well, this is far from the case. In fact, water supply pricing illustrates the kind of policy reform that satisfies both environmental and economic criteria, the rationale for improved water pricing and the impediments to reform being of generic relevance in considering the use of economic instruments in environmental management.

Investment in Water Supply: the Traditional Approach

Pricing and investment decisions in the real world often diverge sharply from the marginal cost pricing ideal, and this is clearly illustrated with respect to municipal water supply, as well as for other services such as electric power or highway systems that are traditionally provided - or regulated - by the public sector. When faced with actual or impending water shortages, water authorities throughout the world tend to estimate future "requirements", typically by extrapolating past trends in consumption, adjusted for expected increases in population and industrial growth. The objective then is to attempt to meet the targeted consumption at least financial cost to the utility. The question of comparing benefits of projected consumption growth with the cost of incremental supply rarely arises. Indeed, benefit-cost estimation, in which an analyst attempts to impute the value of water in a wide array of different uses, is fraught with difficulty. In practice, the only way in which a reasonable assessment of the desirability of a particular rate of increase in water consumption can be made is by actual observation of consumers willingness to pay.

Pricing of water, as of other resources, is therefore not simply a matter of raising revenues to ensure the continued operation of the enterprise concerned, although this is of course a major function of pricing. What concerns us here is the role of pricing in ensuring that the expansion of capacity and consumption is at the correct level. The pricing approach in effect places the burden on the consumer to reveal willingness to pay - and therefore value - of water consumed. If the price paid is at least equal to the costs of providing additional supplies, investment in additional capacity is warranted; if not, existing capacity should be rationed. To illustrate, it would be desirable if an industrial consumer based a decision to invest in recycling equipment by comparing the cost thereby incurred with the cost to society of investing in additional water supply capacity. Clearly, this will only be done if the water price faced by the industrial enterprise actually equals the cost to the water utility of expanding output. Incremental or marginal costs, rather than historic or sunk costs are therefore relevant for investment decision making. This forward-looking approach to pricing can provide a rigorous test of project justification if various other conditions are met with regard to the functioning of the market mechanism in general.

Ideally, the price charged for water should equal its economic and environmental costs of supply, plus the cost of disposing of wastewater, and should therefore vary from location to location, and sometimes according to time of use. Where actual shortages occur, prices should be even higher than actual system cost, at a level sufficient to ration existing capacity. Where private abstraction of water depletes existing sources, necessitating additional investment either by other firms or public water authorities, a similar charging principle should be used.

While there are a number of complications, there is clearly considerable scope for water pricing reform in most countries. While some will gain and others lose from such reform, adjustment of tariff structures can protect deserving cases. However, from a societal point of view, price reform can be expected to be a "win win" policy, in which various economic and social objectives can be satisfied. Studies done in industrial and developing countries suggest that water price increases have a significant impact upon water consumption, reducing wasteful and inefficient use and costs of supply, and improving resource allocation. Such a policy will also raise revenues and be environmentally benign.

The Concept of MOC

We now look more closely at the concept of marginal cost, and define it more specifically as marginal opportunity cost (MOC), which emphasizes that costs of consuming resources should ideally be looked at in light of the opportunities foregone by that consumption. In fact, MOC may usefully be defined to include a number of distinct elements. Specifically, for non-tradeable goods or services:

MOC = MPC + MUC + MEC
where:

MPC is the marginal production (or private) cost,
MUC is the marginal user (or depletion) cost, and
MEC is the marginal environmental (or external) cost.

Marginal Production Cost. This includes the costs of production directly incurred by the agency concerned. In the case of water supply, MPC consists of those investment and operating costs that are a function of water consumption. These would include the cost of dams, river intakes, transmission mains and treatment works, and some distribution costs. Overheads including meter reading and maintenance unrelated to actual consumption would not be included. As in the case of the other elements of MOC, costs should be defined in economic terms; in other words, overall costs to society as a whole should be used, rather than just those incurred by the enterprise. The financial costs of the enterprise should therefore be adjusted to compensate for general market distortions, with shadow pricing being used as necessary. Production costs should also be adjusted if inputs (labor, capital or energy) used are subsidized by the government. To obtain the true production cost we must add an amount equal to the subsidy. If taxes are included in private production cost they should be deducted since they do not represent a real cost, but only a transfer item.).

Marginal User Cost. Consumption of non-renewable resources may eventually require a substitute to be found for them at some future date. The cost of future use foregone is known as the user cost, or depletion premium. In practice, estimation of MUC may often be difficult, as it may involve prediction of costs of depletion or of substitutes many years hence. It will be shown below that there is sometimes some ambiguity in definitions: in certain cases, MUC is conceptually very similar to MPC. The distinction is however required when irreversible effects take place; even when they do not, the distinction is useful for pricing purposes. Note that depletion costs exist because of market imperfections. If property rights are clearly defined and if social and private discount rates coincide, MUC will be included in MPC.

Marginal Environmental Cost. Environmental costs, or externalities may arise at the production stage (MEC_1) and/or consumption stage(MEC_2), and may be positive or negative. For example, dam construction might damage local eco-systems, but may also result in flood control benefits. Water consumption might yield health benefits, not simply to the actual users, but also to others. On the other hand, discharge of wastewater creates negative externalities. Note that to the extent that some portion of environmental damages are recovered by government, for example by pollution taxes or regulatory mechanisms, MEC will already be incorporated in MPC. The presence of market failure, which gives rise to the need to estimate the present worth of environmental damage in the first place, is itself a reason why innovative methods must often be devised to impute reasonable values for MEC.

Private abstraction. Many industrial water consumers and farmers abstract water privately, using their own tubewells. In principle, they should be charged a price that covers the marginal costs of depletion to their neighbors, or the marginal capacity cost to the public authority, plus any environmental damage caused by the discharge of wastewater.

Tradeables. Where the resource concerned (such as coal or timber, or in rare instances, water) is tradeable in international markets, MOC may be defined more broadly as follows:

MOC = (MPC + MUC + MEC) **or** the border price, whichever is the greater

For example, as long as the marginal cost of producing the resource domestically (MPC + MUC + MEC_1) is less than the f.o.b. export price, the resource should be used to satisfy domestic demand (at the border price), and any surplus exported. Domestic prices should equal the export price (adjusted for the difference between the domestic transportation cost of exports and transportation cost related to domestic consumption), because the true cost (opportunity cost) of domestic consumption is the amount that a foreign buyer would be willing to pay for it. In addition, domestic consumers should bear the costs of any consumption externalities (MEC_2). This may be achieved by several means, including specific charges or regulatory instruments for the emission of wastes into the air, waterways or sewers. Somewhat blunter instruments, such as inclusion of expected MEC_2 in the price of the resource concerned can also be used. Examples include incorporation of the costs of sewage collection, treatment and disposal in water prices; and the costs of expected damage caused by SO_2 emissions in the prices of various qualities of coal.

Output quantities for which (MPC + MUC + MEC_1) is greater than the c.i.f. import price should not be produced domestically at all, but imported instead. If for some reason the government does not wish to be dependent upon a foreign supplier, and insists upon domestic production, the local price should in this case be (MPC + MUC + MEC_1) plus some means of assigning responsibility for MEC_2, as outlined in the previous paragraph. As a long term policy, domestic production for which MOC is greater than c.i.f. import prices is untenable under free trade conditions; it can only be effected through production subsidies or import tariffs which reintroduce a wedge between private and social opportunity costs.

Application of MOC pricing as described above is in practice confronted by a number of problems. First of all, a number of conceptual and issues arise in the estimation of MOC. Actual implementation also faces a series of conceptual and practical obstacles. The remainder of this paper now addresses these two sets of issues.

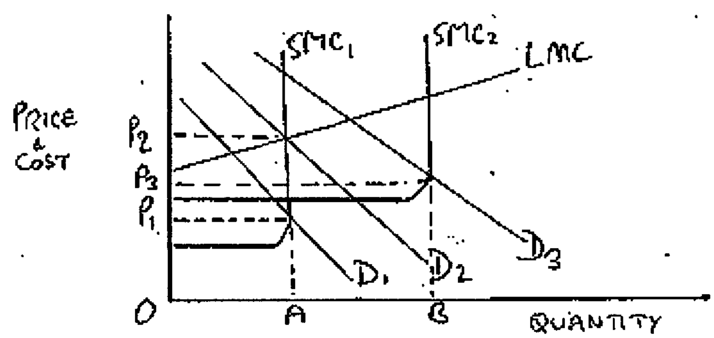
B. ESTIMATING MOC

Marginal Production Cost

Capital Indivisibility: AIC Pricing. A distinction must be made between those costs that are a function of consumption and those that are not. Ambiguity in the definition of marginal cost arises where capital indivisibility (or "lumpiness") is present, for, with respect to water supply capacity and consumption, costs will be marginal at some times and non-marginal at others. For example, if the safe yield of a reservoir is less than fully utilized, the only costs immediately attributable to additional consumption are certain additional operating and maintenance costs. These represent short-run marginal costs. Long-run marginal costs, on the other hand, refer to the sum of short-run marginal costs and marginal capacity costs, the latter are defined as the costs of expanding capacity -- for example, building a new reservoir -- to accommodate an additional unit of consumption.

The two definitions of marginal cost, one applicable in the short run and the other in the long run, have to be reconciled, for a pricing policy which is associated with an optimum use of existing capacity will frequently not be one which results in optimal decisions. Strictly interpreted, the marginal cost pricing rule requires that price should equal short-run marginal cost when capacity is less than fully utilized, but if demand increases so that existing capacity becomes fully utilized, price should be raised to ration existing capacity. This procedure should continue up to the point where consumers reveal their willingness to pay a price equal to short-run marginal cost plus the annual equivalent of marginal capacity cost. At this stage, that is, where price equals annual equivalent long-run marginal cost, investment in capacity expansion is justified. Once the investment has been carried out, however, price should fall again to short-run marginal cost, for the only real costs (or opportunity costs, in terms of alternative benefits forgone) are then operating costs. Price, therefore, plays the roles of (a) obtaining efficient utilization of resources when operating at less than full capacity, and (b) providing a signal to invest in additional system capacity.

The foregoing is depicted in the following diagram:



In this diagram, initial demand curve is D1, and existing supply costs (with capacity OA) are represented by short run marginal cost curve SMC1. As demand increases to D2, price should be raised to ration existing capacity OA up to the point where consumers reveal their willingness to pay a price that will cover long run marginal costs (LMC, which consists of short run costs plus the annual equivalent of marginal capacity costs). At this point (P2) investment should be carried out, increasing capacity to OB. However, since there is now excess capacity, marginal costs are again just the operating costs, in which case price should fall sharply to P3. As demand increases, price should again be raised until it equals LMC, thus providing the signal for further investment, and so on.

Problems associated with strict marginal cost pricing, as just described, are therefore particularly apparent in the presence of capital indivisibility. This characteristic is however typical of water supply projects, where productive capacity is often installed to meet demands for a number of years hence. Initial costs of constructing reservoirs and laying connecting mains are usually very high in relation to operating and maintenance costs. Strict marginal cost pricing in these circumstances would entail significant fluctuations in price, a source of considerable uncertainty for consumers, which would create particular problems for planning long-term investment in facilities complementary to, or competitive with, water consumption. Exploitation of groundwater -- the primary source for rural systems -- often gives rise to less difficulty in this respect; in the economist's jargon, the long-run marginal costs curve is frequently relatively "smooth". Even where it is technologically possible to extend capacity in small increments, however, fluctuations in the availability of finance often mean that capacity is extended in large lumps. This issue is particularly important in developing countries, where large backlogs in supply may be remedied and excess capacity created at the same time.

One solution -- necessarily an imperfect one -- to the problem of capital indivisibility is to define marginal cost more broadly, and to set price equal to the average unit cost of incremental output. Average incremental costs can be calculated by dividing the discounted value of future supply costs by the (similarly discounted) amount of additional water to be produced. In practice, any version of marginal cost pricing has to be approximate, and ultimately some averaging of costs over a range of output is always required. Average incremental costs pricing will be theoretically less desirable the greater the degree of capital indivisibility, for while capacity remains idle, price will be in excess of the currently relevant marginal cost. However, in view of the difficulties inherent in any system requiring fluctuating prices, this method appears to be the best practicable approximation to optimal pricing that can be achieved in the water supply field; it also provides a relevant signal about cost trends to those who contemplate long term investment in equipment that is complementary to or a substitute for water use. Estimation of future engineering costs over a time horizon of 20-25 years is generally required. Since it is rare that expansion of water supply capacity involves a series of technically similar investments (cities bordering major rivers such as the Yangtze are an exceptional case), the use of statistically determined production functions to estimate costs on the basis of time series or cross sectional analysis is rarely appropriate.

AIC is estimated by dividing the discounted incremental costs of meeting future demand by the corresponding discounted volume of incremental output over the same period. The numerator in the AIC formula is the present value of the least-cost investment stream plus the incremental operating and maintenance costs. The time stream of investment and operating costs in the numerator corresponds to the production stream over time in the denominator. The AIC formula is therefore:

$$AIC = \frac{\sum_{t=1}^{T} (I_t + R_t - R_o) / (1 + r)^t}{\sum_{t=1}^{T} (Q_t - Q_o) / (1 + r)^t} \qquad (1)$$

where I_t is the investment cost incurred in year t, o is the base year, $R_t - R_o$ is the operating and maintenance cost incurred in year t due to incremental consumption, $Q_t - Q_o$ is the incremental consumption in year t, and r is the discount rate.

Increasing unit costs. Increasing unit costs of water tends to be the rule, as sources close to urban areas become fully utilized or polluted. This also applies to a number of other natural resources, where technological improvement and economies of scale are not sufficient to offset other forces. For example, in the case of forest operations, the cost of cutting and transporting a cubic meter (cu m) of timber does not remain constant regardless of the total amount of timber production. The more timber that is produced each year, the higher cost of producing an additional cu m of timber, because of limiting factors such as the use of less experienced logging crew, overstretched management, transportation bottlenecks and the need to exploit increasingly more remote, or steeper forest sites. A similar set of considerations typically applies to the exploitation of coal reserves of a given quality.

Distribution Networks. Capital indivisibility is demonstrated in an extreme form by both water supply distribution networks and by sewerage systems. Prior to construction, expansion of such systems is, by definition, a marginal cost and function of the expected consumption of those benefiting from it. These systems are however normally designed to meet demands placed upon them for many years hence, during which time additional consumption by existing consumers is responsible for negligible additional distribution capacity costs. The pure marginalist approach would suggest that the price charged for these services should also be negligible. They have to be financed somehow, though, and this may result in conflict often between economics, social, and financial objectives.

Temporal and Locational Variations in Costs. The marginal cost pricing principle implies that price should reflect variations in the cost of supplying water to different types of consumer. It may therefore be desirable to distinguish between consumption at different times and at different locations. In the case of water supply, the cost of consumption may sometimes be expected to vary seasonally. If so, whether pressure on capacity is due to demand peaks or supply troughs or both, there may be a case for varying the price of water to achieve an efficient allocation of supplies. In some cases, such as abstraction from rivers or groundwater, marginal capacity costs (of pumping equipment, transmission mains etc) can be allocated to peak consumption, with marginal operating costs, which may vary seasonally, being allocated to all consumption. Where storage in reservoirs is involved, off-peak consumption, by drawing down the level of a reservoir, might also impose marginal capacity costs. Estimation of the appropriate peak and off-peak pricing policy therefore depends very much upon the type of water system involved, but in strict efficiency terms, such a distinction will frequently be justified. In practice, it would only be possible to introduce differential pricing for seasonal peaks: the need to meet diurnal peaks is reflected in the design of distribution systems, and differential pricing here would, **prima facie**, be too expensive to administer.

Geographical variations in marginal costs should also be reflected in pricing policy. The use of national or state-wide uniform tariffs, which in developing countries is fairly widespread and seems to be growing, is clearly at odds with the principle, and may be responsible for inefficient locational decisions, particularly by large water-using industry. Occasionally, there may also be scope for distinguishing between consumers within a given urban area: connection and distribution costs may vary with population density, while consumption costs (pumping, etc.) may vary according to terrain.

A number of political and social difficulties arise in attempting to ensure that temporal and locational variations in costs are reflected in pricing policy. In many cases, because the "need" for water is more apparent during the dry season, it is particularly difficult to levy a surcharge on consumption at that time. Regarding geographical cost variations, one explanation for the increasing pressure for uniformity is the improvement in communication which allows people in various parts of the country to know what is going on elsewhere. Failure to allow prices to reflect regional variations in costs on the grounds that this is equitable may have perverse effects, one of which might possibly be that poor consumers in low cost areas in effect subsidize high income consumers in high cost areas.

Regional variations in supply costs are substantial in many countries. In China, the south tends to have abundant water resources, while the north has shortages. Expensive schemes are proposed to transfer water from south to north, including plans to transfer water from the Yangtze basin to Beijing. Improved pricing for water supply in the Beijing area is an urgent issue, and one which can yield tangible and substantial economic gains. In particular, long term benefits would take the form of a more rational geographical distribution of large water-using industry.

Marginal User Cost

The concept of MUC can be explained most simply where a non-renewable resource is involved. Since it is fixed in supply, continued exploitation into the indefinite future is not possible; exhaustion of the resource will eventually occur. Consequently, using one unit of the resource now means that it will be unavailable at some future date. The seriousness (or cost) of consumption now will obviously depend upon the size of the stock; the rate of exploitation; the cost and availability of substitutes at some future date (including, for tradeables, world prices for an import substitute); and the rate of discount. Substitution might be achieved by imports or by using a replacement "backstop technology".

The cost of future use foregone is known as the user cost or depletion premium, and may be estimated as the present worth of the cost of replacing the depleted asset at some future date. The user cost is therefore the difference between (a) the present worth of the marginal production costs of the replacement technology, or of the costs of imports, and (b) the present worth of the marginal production costs of the existing technology i.e:

$$MUC = (P_b - C)/(1 + r)^T$$

where P_b is the price of the replacement technology (or of imports), C is marginal cost of extraction, harvesting, or marginal production costs of existing technology, r is the discount rate, and T is the time at which the replacement technology comes in, or when imports are required.

Major uncertainties may arise in the estimation of MUC; in particular, the availability and cost of backstop technology may be very difficult to predict. However, while problems of prediction increase with time, they also become less important for the MUC estimation. MUC will be smaller, the greater the stock, the lower the rate of exploitation, and the longer the time horizon prior to exhaustion of the resource. For example, in China, which has abundant coal reserves, the MUC of consuming coal at the present time is insignificant; on the other hand, exploitation of its few remaining tropical forest areas would appear to have a relatively high MUC. Note also the role of the discount rate; other things equal, the higher the rate, the lower the MUC.

The foregoing describes the simplest case to illustrate the MUC concept; particular complications arise with regard to the treatment of resources that are in principle renewable, but in practice, due to overuse, may not be. The sensitivity of the results to slight changes in assumptions about exponential variables combined with uncertainty about the future indicate that the MUC calculation should be regularly updated if the concept is to be useful.

It should also be noted that in certain circumstances, MUC may already be included in MPC. This might apply where there are competitive markets, implying a clear definition of property rights, and a coincidence between social and private discount rates. However, these conditions are rarely encountered, particularly as they relate to the ownership and rights to exploit natural resources such as forests, coal, and water in most developing countries.

With further regard to the relationship between MPC and MUC, let us assume that depletion takes place in year T. The depletion premium is defined as the **additional** cost over and above the cost of production from existing sources (incurred because of the more expensive backstop technology or imports), also discounted to present worth from year T. MPC+MUC may be defined as the sum of the discounted value of the cost of operating existing sources (or the AIC of these) plus the discounted value of the depletion premium (or its AIC). Since MUC represents the difference between the cost of existing technology (MPC) and that of the backstop technology, MPC can be calculated simply by inserting the new technology in the cost stream; indeed, there is some ambiguity in determining at what stage an increment in supply actually represents a backstop technology. This is particularly difficult in the case of water supply, where technology is continually changing, for example as sources further and further from the point of consumption are exploited, and as unit costs are rising. Fortunately, the ambiguity does not pose a serious problem; in estimating MOC it does not matter whether MPC is defined to include the full cost of backstop technology or whether the additional costs are separately designated as MUC.

It might therefore be asked why it is necessary to separately identify the MUC component. A difference between the social discount rate and the discount rate of the utility manager would be sufficient reason. In practice the distinction is useful in highlighting those cases in which resources are in danger of depletion and in which strategic decisions need to be made regarding substitute technology or imports. Moreover, depletion costs due to incremental consumption may be higher at some times than at others; the concept of MUC may therefore be relevant for the design of tariff structures, particularly where seasonal differentiation in pricing may be warranted. A further reason for the distinction between MPC and MUC is that the latter may call for different analytical skills, particularly when irreversible effects are involved.

Marginal Environmental Cost

In estimating MEC, a distinction should be made between those environmental externalities that are associated with the production of water, and those associated with actual consumption. These may be positive or negative. For example, the construction of a dam may involve damages to the local eco-system, threaten endangered species, or force human beings to abandon their homes, but may, on the other hand, have flood control benefits. This element of MEC may be labelled MEC_1. Consumption of water may also involve external or environmental effects; health benefits might result not only to actual consumers, but also to their neighbors or associates. Estimates of health impacts require epidemiological analysis, followed by valuation in economic terms.

Further, consumption of water involves disposal costs. Where sewers exist, or are planned, AIC can also be used, on the assumption that such expenditures are in fact economically justified. Where sewerage does not exist, there is no escape from some estimation of MEC, which again requires estimation of the epidemiological impact and quantification of that effect in economic terms. While MEC_1 may be the same for all consumers, the environmental consequences of actual consumption, (MEC_2) may be expected to vary according to the type of use. The quality of industrial wastewater, for example, can be expected to vary considerably among types of industry, and generally be more hazardous that household discharges. Optimal pricing would clearly distinguish between MEC_1 and MEC_2. While clearly relevant for water supply, this distinction is perhaps even more important in the case of certain other resources, such as coal.

As in the case of MPC and MUC, the MEC calculation also involves a time dimension, as it refers to the present worth of incremental environmental or other external damage costs. MEC could be included in MPC where marginal damage costs are internalized, e.g. where industry is charged for pollution emissions according to the marginal damage costs created. However, in practice, MEC_1 is generally far greater than the environmental costs incurred by polluters. (The distinction between production and consumption externalities is particularly important in the case of coal, where damage created by actual mining operations (subsidence, water and soil pollution) is very different to that occasioned by final consumption, where air pollution is the primary concern.) Whether or not environmental damage is actually internalized in this way, or by blunter instruments, such as incorporation of environmental cost (MEC) in water or electricity prices, valuation techniques are required.

In principle, the range of valuation techniques that economists have developed may be relevant for water supply pricing. Market value approaches offer the best prospects where "dose-response" relationships can be established. These include the health impact of water pollution, and the damage to crops resulting from water resource development projects. Most of the skills required are those involved in establishing these physical relationships, such as epidemiologists and ecologists. Household production function approaches may also be used: estimation of avertive expenditures, such as expenditure on water filters may provide some indication of willingness to pay for improved water quality; travel cost methods have also been used to assess the value of recreational areas, which may be positively or negatively influenced by water supply projects. Hedonic pricing methods have also been used; these include the impact of water supply and sewerage projects on property values, and the estimation of the impact of environmental factors on wage rates. Currently much effort is devoted to contingent valuation methods, in which surveys are used to assess the value of environmental change.

The MOC Calculation: An Illustrative Example

Numerical examples of the MOC calculation, in which the AIC formula is used to determine the cost per cu m of water, are presented in Tables 1 and 2. Cost and consumption data are discounted back to 1994, and all estimates are presented as values as of that date. While costs are presented in terms of $ per cu m., they do not purport to relate to the currency of any particular country. A 5% discount rate is used throughout. Table 1 includes estimates of the costs of supplying water over the 1994-2015 period, using conventional technology, such as pumping water from an underground source. The data show consumption growing up to the year 2010 and then stabilizing, due to the exhaustion of available capacity. This is an unrealistic assumption in normal circumstances, but if it did materialize, the AIC of production (MPC), calculated in 1994 would be $2.50 per cu m. MEC is shown to be $2.00, and total MOC is therefore $4.50. As an example of how these calculations are done, AIC (production costs only) is estimated by summing the present worth equivalent of each annual cost in Column (4) and then dividing this amount by the sum of the present worth equivalent of each annual amount of consumption shown in Column (7).

It should however be noted that if actual consumption stabilizes due to capacity constraints, while demand continues to increase, the opportunity cost of consuming water (in terms of amount other consumers would have paid for it) increases. In fact the MOC pricing rule requires that prices should equal either the cost of consuming incremental amounts, or the market clearing price, whichever is greater. Clearly, therefore, the $4.50 price in these circumstances would understate true MOC by an amount that would depend on how high the price would ideally be bid up when existing capacity becomes fully utilized. (Similarly, the opportunity cost of municipal water supply may be its highest value in different uses altogether, such as agriculture or direct abstraction by industry.) When existing sources of water are fully utilized, MUC would be the price necessary to ration capacity, minus MPC. Investment in backstop technology would be signalled when consumers reveal their willingness to pay a price over and above marginal production costs sufficient to cover the additional costs of backstop technology.

MEC in this example does not explicitly distinguish between environmental costs associated with exploitation of water sources (MEC_1) and those associated with wastewater disposal costs (MEC_2). As noted earlier, the latter could refer either to the external environmental damage caused by the discharge of wastewater into neighborhoods or rivers, or could refer to the wastewater disposal costs actually incurred by municipal authorities in the form of sewerage and sewage treatment works. In principle, the cost of these investments, also characterized by capital indivisibility, could be handled similarly to water supply, but for simplicity annual costs with a linear relationship to water consumption are assumed in the example.

Table 2 then presents estimates of MOC in cases (a) where a new "backstop" technology (such as desalination) is introduced in year 2010, and (b) where imported water is used to augment capacity in years 2010 and thereafter. Instead of levelling off at this date, incremental consumption and associated production and environmental costs continue to increase up to the (arbitrary) cut-off date of 2015. Using as before an AIC formulation, the MOC associated with the backstop technology solution is estimated at $7.21 per cu m. From Table 1, MPC of production using existing conventional technology, is $2.50. MUC, which is defined as being the excess of the present worth of unit production cost using backstop technology over that with conventional technology, is therefore $2.71. Unit environmental costs are unaffected by the source of water, and remain at $2.00 per cu m.

For purposes of illustration, this example assumes that the country concerned is one that finds it feasible to import water from abroad. Importing water as an alternative to the use of expensive backstop technology in this case appears in fact to be slightly cheaper, the MOC as of 1994 being estimated at $7.13 per cu m. It will be observed that in this case water, whether imported or produced by desalination, may be regarded as a homogeneous commodity. The estimates are unaffected whether the additional costs of the backstop technology or of imports are defined as part of MPC or whether they are labelled MUC.

Note that for convenience a cut-off point for the calculation is at year 2015. While the import alternative appears to be cost-effective when 1994 is used as the base year, this may change over time, and re-calculation should be carried out year by year to ensure that changes in relative prices (including discount rates) are taken into account. In particular, the viability of the backstop technology compared with imports will also depend upon the useful length of life of the desalination plant, the estimates in this example being cut off only 2 years after its commissioning in the year 2013. (While evidently unrealistic, this assumption is relatively unimportant given the effect of the discounting procedure. However, the estimated useful life becomes not only more realistic when the calculation is done for succeeding years - the 25 year time horizon being maintained - but also more significant).

The results are also sensitive to different assumptions about discount rates, as shown for rates between 2% and 15% in Table 3. MOC under both the backstop technology and the import scenarios is higher than that for the conventional technology at all discount rates. In the example, the import option is more expensive than the backstop technology at a discount rate of 2%, but cheaper at the higher rates. (As noted above, however, this might change over time, as the true relationships between the backstop technology and import alternatives are revealed in the cost streams).

MEC is assumed to be proportional to water consumption, and is not affected by changes in discount rates. It will however be observed that the higher the discount rate, the higher is the MPC of the conventional technology program. In fact, this is the traditional pattern observed in cost-benefit analysis, where net project costs in the early years are followed by net benefits, where higher discount rates reduce the present worth of net benefits. However, the reverse applies when either the backstop technology or the import alternative are incorporated into the production cost stream. In these cases, production costs increase at a faster rate than actual consumption when conventional sources become depleted; where this is so, a higher discount rate tends to reduce the MPC. This illustrates the generic principle that the magnitude of the MUC is inversely related to the discount rate, this being shown in the table to fall from $3.03 to $1.63 per cu m. as the discount rate increases from 2% to 15% Although not shown in the table, it is intuitively clear that extending the time horizon before the backstop technology or imports are required will also lower the MUC.

Data requirements for the MOC calculation are clearly demanding. Most of the basic consumption and engineering data should be available from feasibility studies in the case of well run utilities. Adaptation of engineering cost data to reflect economic costs will require national level parameters for shadow prices which should be available from national planning agencies. Adjustment to reflect local or sector specific conditions with regard to costs and consumption will typically require original research. Where existing studies provide inadequate cost data, perhaps because certain technical alternatives have not been considered, efforts should be made to obtain the best judgement from engineers experienced in cost estimation. In general, experience in doing this kind of work often is valuable in indicating to those ultimately responsible for water supply the kind of information that an efficient organization should have, but often does not.

C. IMPLEMENTATION

Having estimated MOC, the next question is how to implement a price policy based upon this concept. In principle, the steps to be followed in using MOC to bring about an optimal rate of system expansion are as follows:

(a) Estimate future water "requirements" over a 20-25 year period, in light of planned industrial investment, population growth and income and price elasticities, and other specific variables such as the presence of sewerage.

(b) Design the least cost program for meeting the foregoing requirements. (i.e. investment and operating costs of production plus external costs plus user costs discounted to a present worth, where all costs are defined in economic rather than in financial terms).

(c) Set price equal to MOC (based upon (b), and using the AIC methodology).

(d) Observe the reaction of consumers to the price change, i.e. re-estimate water requirements (as in step (a)).

(e) Re-estimate the least cost program for the new water requirements (as in step (b)).

(f) Re-estimate MOC, and continue the above procedure by a series of iterations until an equilibrium is achieved.

The foregoing may be incorporated into a predictive model which will, in effect, iterate between various estimates of MOC, water demand, and least cost solutions, to arrive at an equilibrium solution. In practice, however, there are a number of obstacles to the straightforward application of MOC pricing for water supply. These include: inadequate data on demand elasticities; the presence of externalities; the metering problem; a variety of financial and fiscal issues; providing service to the poor; and shadow pricing and second best considerations.

Price Elasticities

A number of studies provide general evidence that price elasticity of demand is sufficiently high to make the topic of water pricing an important one from an efficiency standpoint, i.e. that raising price from current low levels to one based upon marginal cost will in fact result in substantial net savings. A World Bank/Overseas Development Institute study reports that in a number of developed countries - Israel, Canada, United States, Australia and Great Britain - empirical analysis has shown that the price elasticity of demand for water by households is between -0.3 and -0.7, (i.e. a doubling of the price of water would reduce consumption by between 30 and 70 percent). A similar range of elasticities is reported from studies of a number of developing countries in Asia and Latin America. There is also much empirical evidence about the potential substitution of capital for water in industry. For example, substantial increases in industrial water prices in Japan in the mid 1970's stimulated major investments in recycling, and sharp reductions in consumptive water use.

Such general evidence is of course no substitute for empirical analysis of specific water systems in developing countries, since a host of variables may be very location-specific. These include type and quality of housing, per capita income and its distribution, the structure of industry and commerce, the means of wastewater disposal, as well as the costs of incremental supplies. Note also that statistical analysis based upon cross-sectional or time series analysis may often be frustrated by data problems, including measurement of actual water consumption, with system losses (often as much as 50% of total production) and non-existent or inadequate metering of individual premises also contributing to the problem. Water shortages, often associated with low prices, may also be a major determinant of actual consumption, and the identification problem is frequently encountered. Moreover, while short term price elasticities may be identifiable, this may not be relevant for investment planning. As consumers adapt to price changes, it can be expected that demand will become more elastic; but long term elasticities are also difficult to estimate since price effects are often swamped by the influence of other variables. Nevertheless, the potential gains from refining knowledge of demand determinants suggests that empirical work in this area, perhaps involving production function analysis for large water users, would be useful.

Externalities

The observed willingness of consumers to pay for water or sewage facilities may be an inadequate indicator of social value where externalities are associated with such services. Thus, an external benefit that might result from the consumption of potable water by X is that the health of his neighbour Y might improve as a consequence. Since X would not take the health of Y into account in his decision to consume potable water, his willingness to pay would tend to understate the benefits that would accrue to the community as a whole. MEC in this case would be negative. (Note that whether related to direct or external benefits, a normative judgement based upon the evidence of willingness to pay has to assume that the consumer is well informed about epidemiological relationships; clearly, such an assumption is often unjustified).

The externality problem with regard to sewerage is particularly complicated. In viewing it, it is important to distinguish between sewage collection on the one hand and sewage treatment and disposal on the other. The benefits of connection to a sewerage system are fairly direct, and willingness to pay can be identified. On the other hand, the benefits arising from actual sewage treatment may be several miles from the properties that are connected to the sewers, so willingness to pay by actual waste dischargers is unlikely to express social benefits adequately. Independent valuation of such benefits is thus required; health impacts are likely to be the dominant benefit in the case of sewage collection and disposal, along with aesthetic, recreational, or savings in water production costs. The health impact of improved sewerage facilities will tend to be greater in more densely populated urban areas because of the lack of unpolluted water supply and the greater chance of contagion. On grounds of externalities, where consumers are unaware of the advantages of clean water and improved sanitation in improving health, this may point to a policy of consumer education, combined, as an interim measure, with subsidization of basic sanitation facilities in such areas, and this of course is often done.

A perennial issue concerns the appropriate way to charge for water supply and sewerage in cities in which some areas are served with water supply only while others have both water and sewerage. The most common means of dealing with this situation, where water and sewerage systems are operated by the same authority, is to separate the costs of water supply and sewerage, and to levy a sewerage surcharge only for those households actually connected to the sewerage system. Such a policy will often be suboptimal in terms of the criterion that price should equal incremental costs. For those already connected to the sewerage system, the incremental costs of waste disposal are relatively low, since the main element of costs - i.e. the sewers themselves - are "sunk". It can be expected, as long as the original decision to invest in sewerage was economically justified, that the MEC of disposing of wastewater by some consumers currently without sewerage will exceed the MPC of those who are connected. Theoretically, therefore, there may be a case for levying a higher metered water charge for persons without sewerage facilities than for those who are connected to the system. The social/political obstacles to such a policy are apparent, but the general rationale is sometimes used to justify some contribution to sewerage costs from those who do not directly receive this service.

While there are theoretical advantages of basing charges or taxes on the economic costs of discharging wastewater and pollutants into the sewer system, administrative feasibility and the cost of the necessary monitoring suggests that a charge for wastewater disposal based upon metered water consumption will, in practice, have to be a fairly blunt instrument. As noted above, when applied to water supply, marginal cost pricing is a viable means of achieving efficient resource allocation, in the sense of ensuring that the benefits of system expansion exceed the costs. If price is set equal to marginal cost, and consumers demonstrate their willingness to pay such a price, it means that they place a value on the marginal unit consumed at least as great as the cost to the rest of society of producing that unit; output and consumption should therefore be expanded when system capacity is reached. If, on the other hand, the market clearing price is less than marginal cost, it can be assumed that there is oversupply; the cost of additional output exceeds the benefits.

Application of this principle to the disposal of wastewater (the cost of sewerage and sewage treatment) presents a number of difficulties. It is obvious that when - as is common - sewage collection and disposal is financed from general revenues in such a way that there is no relationship between payment and benefits, the source of finance cannot be used to impute willingness to pay. Moreover, if sewage collection and disposal are charged for on the basis of metered water consumption, a revealed willingness to pay a given price simply indicates a value placed upon incremental water consumption plus its disposal. It is not possible to determine the extent to which willingness to pay refers to water supply alone or to water supply plus its disposal through the sewerage system. Allocation of costs or revenues between water and sewerage by the utility is in practice purely a bookkeeping matter, and provides no guidance for resource allocation. Consequently, to place normative significance on willingness to pay for water supply plus sewerage implies the judgement that sewage collection and disposal facilities are a necessary accompaniment of investments in water supply. While a popular notion, this is usually based upon intuitive judgement, and avoids the fundamental question of how to justify the sewerage component alone.

Placing a surcharge on water consumption which covers incremental sewerage costs does however have certain advantages from an economic standpoint. Although it does not assist in the sewerage investment decision, such a pricing policy is required if water and sewerage capacity is to be utilized most efficiently, and in particular that the least social cost means of disposing of wastewater is achieved. The water consumer is provided with an incentive to use the water supply and waste disposal facilities up to the point that the marginal private benefit equals the marginal system cost, and **given the decision to invest in a particular means of wastewater disposal**, optimality is achieved. This is a sufficient argument to justify charging for sewage disposal on the basis of metered water use. However, for it to be effective even in this limited sense requires that water consumers be categorized according to the type of waste they discharge into the system, and charged accordingly. In practice, this will be difficult to do; and even if such categories can be developed, a charge based upon water consumption (as opposed to one levied individually on actual discharges) is a blunt instrument that does not have - as an effluent charge would - the merits of distinguishing between users according to the quality of effluents actually discharged into the sewers.

The discussion thus far is applicable only to those water users who are already connected to a sewer. The difficulty of determining willingness to pay for connection to any system by advance testing of the market is well known - sewerage being similar to water supply, electricity, and so in this regard. Analysis of experience in other similar situations is necessary in order that estimates of the willingness of potential beneficiaries to pay connection fees and other sewerage-specific charges can be made. In principle one could impute the value that a householder places upon the connection of his home to a sewerage system from his payment of (a) a connection charge, or (b) a tax, the magnitude of which is in part determined by his connection to a sewer and which could include the additional water charge he is likely to pay, This, however, requires that the householder has an option to connect or not to connect, and therefore to pay or not to pay for the service. If, as is often the case, connection of houses to a sewer placed under a particular street is compulsory for all houses on that street, freely expressed willingness to pay for sewerage is not revealed. Evidence of willingness to pay may also be obtained by expenditures on alternative means of wastewater disposal such as septic tanks, or on the basis of the impact of sewerage construction on land values.

The Metering Decision

A traditional obstacle to improved pricing for water supply and its disposal - and one which is highly relevant for pricing environmental services in general - is the measurement of the quantity of water consumed and the quantity and quality of wastewater discharged. The introduction of metering, which in effect raises price at the margin from zero to some positive figure may be expected to reduce consumption, thereby deferring the need for capacity expansion, and saving in water system operating costs. However, the introduction of volumetric pricing may be more expensive than allowing water to be free at the margin. Whether or not to invest in a metering programme, for which class of consumer, and the optimal timing of such decisions is in fact a suitable subject for cost-benefit analysis.

In principle, the decision should be based upon a comparison of the present worth of the costs of the metering program (i.e. installation, maintenance and replacement of meters, and meter reading and additional billing costs) with the present worth of the savings in production costs thereby achieved, plus the loss of consumer surplus resulting from reduced consumption. Where, as is normal, there is uncertainty about demand elasticity - the extent to which consumption will actually fall when metering is introduced - so-called "switching values" can be used. In this case, the percentage reduction in per capita consumption necessary to achieve savings sufficient to offset metering costs can be estimated, and a judgement then made as to its likelihood. Clearly, the higher the MOC of water consumption, and the lower the cost of metering, the more likely that metering will be justified. Typically therefore metering should be employed for large industrial users, where metering costs are low relative to consumption while it may not be justified for certain other categories, such as individual apartment dwellers, where metering costs are high, and per household water consumption low. If the switching value shows extreme values - e.g. unreasonably high or negligible reductions in per household consumption required to justify the introduction of volumetric pricing - it is easy to make a judgement as to whether or not metering is justified; if not, at least major errors in installing meters can be avoided. Considerable variations in the relevant variables exist both between and within countries, so there is much scope for this type of analysis.

Where metering is not feasible, alternative financing methods have to be used. These may include charges based upon property value, or property size. In practice such methods often represent an uneasy compromise between ability to pay and fairness, with regard to the amount of water that is generally consumed by a particular consumer group. Considerable dissension often arises in determining equitable charging schemes for certain types of commercial activity. Some of these may consume small amounts of water, so metering may be unjustified; however, the property value proxy may result in excessive charges.

Financial Viability and Economic Efficiency

Marginal cost pricing results in financial losses to an enterprise when average costs are falling, that is, when marginal cost is less than average cost. This situation could be temporary, arising for example when there is excess capacity and price is equated to short run marginal cost. It might also be a situation of some permanence, even if there is perfect capital divisibility if long run average costs continued to decline and price is equated to long run marginal cost. If there is capital indivisibility, a price equal to AIC would in these circumstances also result in loss making.

Failure to cover financial costs may have adverse consequences from a purely efficiency standpoint. First, the accounting losses have to be absorbed somehow, and it will often be difficult to achieve the necessary transfer of real income without creating distortions of consumer or producer's choice as severe as those encountered in deviating from marginal cost pricing. Second, the financial discipline and organizational autonomy resulting from financial viability are often thought to be the best way to ensure efficient operation of the undertaking concerned.

Solutions to this dilemma have been proposed which have usually tried to obtain the best of both worlds: the resource allocation advantages of marginal cost pricing on the one hand and the achievement of satisfactory financial performance on the other. There are, in fact, many variations on a common theme, the simplest of which is a two-part tariff where a water consumer would pay a sum per thousand gallons consumer equal to marginal cost, plus a lump sum covering non-marginal "sunk costs" and other costs unrelated to consumption. In this way, as long as liability to the lump sum payment does not deter anyone from consuming the system's water altogether, optimal allocation may be achieved.

Similarly, efficient allocation may theoretically be achieved by the use of price discrimination based upon the estimated price elasticity of demand. Since prices above marginal cost reduce demand - and therefore output - below the optimum, output reductions are minimized if prices are marked up most where demand is most price inelastic, thereby minimizing the loss of economic efficiency. Although such omniscience is rare, this general approach, popularly known as charging "what the traffic will bear," is often employed to finance water supply; for example, larger residential and industrial consumers may be charged higher prices than smaller domestic consumers. Due to the difficulty of estimating demand elasticities the use of increasing block rates cannot be relied upon to ensure efficiency; and it should be emphasised that the presence of increasing marginal costs of supply system- wide does not justify the use of an increasing block rate tariff structure (the marginal cost per unit of water consumed by large users does not differ from that by small users).

With regard to waterborne waste disposal, the kind of tariff that would tend to result from application of the above principles is likely to consist of two parts. Since the initial investment in sewerage (primarily sewage collection) is such an important element of costs, and one that may contain the capacity for as much as 25 years' load growth, the associated problems of "lumpiness" or capital indivisibility would normally imply the need for a large fixed charge, plus a relatively low commodity charge. The low commodity charge would be based upon water consumption (and therefore sewage flow), and would reflect incremental operating costs plus incremental capacity costs mainly of treatment and disposal works.

Since externalities are so important in decisions to invest in sewage disposal facilities, there may often be conflict between financial aims of the appropriate utilities and resource allocation objectives. For financial reasons, sewerage authorities frequently have to ensure that high income residential areas - where the need for sewers (and perhaps piped water) is less because of lower population density and the presence of alternative means of disposal (septic tanks) - are served before congested low income areas, where from a general environmental view point, the need is greater. In such cases, the financial viability of the utility requires that individual willingness or ability to pay is given more weight in determining investment priorities than the external effects. Clearly, this may not be an economically efficient ordering of priorities, but due to financial constraints water and sanitation authorities frequently find themselves in such a position.

Financial problems associated with marginal cost pricing are however considerably eased in most cases, the normal situation being one in which costs are rising sharply as sources of supply conveniently located to the point of consumption are exhausted, and sources further and further away must be exploited. Where long run average costs are rising, i.e. marginal cost is in excess of average cost, AIC pricing would typically generate financial surpluses. The question of disposing of these surpluses would then arise. A problem associated with the generation of excessive revenues by an industry such as water supply which typically does not operate in a competitive situation is that there is inadequate control over the disposition of the revenues. Wasteful and inefficient operation of the enterprise may be encouraged. There may also be simply political arguments against letting water utilities generate excess profits; the excess profits resulting from MOC pricing might therefore be redistributed as a lump sum to consumers independently of their consumption levels, thereby still satisfying the efficiency criterion. Clearly, specially close regulation of water authorities, whether publicly or privately operated, would be required in these circumstances.

One alternative would be to use the excess revenues to defray other public expenditures and/or reduce taxes elsewhere. Taxes levied on water consumption could be an efficient means of raising public revenues, satisfying various taxation criteria, i.e. contributing to economic efficiency goals, being administratively straightforward, and amenable to adjustment for income distributional purposes. Analogous to the case sometimes made for "green taxes"`in general, a fiscally neutral approach could, if desired, be employed. While in practice the primary objective in most developing country situation is still to increase water prices so that at least financial subsidisation is avoided, it is important to highlight the potential fiscal contribution that can be made - at the municipal or national levels - by MOC pricing.

Supplying the Poor

Resistance to price increases for water is often based on the argument that the poor must have access to supplies sufficient to meet their basic health needs. The real economic cost of water is usually a very small fraction of household disposable income, and this argument rarely has merit; indeed, there is much evidence to demonstrate the willingness of poor people to pay private water vendors much higher prices for lower quality water than that supplied through municipal systems. Moreover, if prices fail to reflect supply costs, expansion of systems to meet growing demands may not be financially feasible. Nevertheless, social or political reasons may require that pricing of water for smaller consumers should be subsidized. There may also be conventional economic reasons: the presence of external health benefits, combined with lack of consumer understanding of health impacts, may also justify subsidization. In general, these considerations might be expected to be more prevalent among low income than among high income consumers.

Subsidization of basic water requirements should rarely pose a serious financial problem for the utility concerned. Typically the bulk of the consumption is by a relatively small number of consumers (large residential, commercial and industrial users). Economic (marginal) costs of water supply are rising virtually everywhere. Marginal costs are thus by definition in excess of average financial costs incurred by water utilities. MOC pricing for all water consumed over and above the relatively small quantity identified as required to meet basic health needs would therefore typically generate sufficient revenues for the utility to operate, and indeed to permit expansion of supply to areas as yet unserved, thereby being directly beneficial to lower income groups.

In practice, a commonly observed approach in developing countries is to make use of a tariff schedule that consists of two steps - a low subsidized "lifeline" rate for the first 6 to 8 cubic meters per month and a higher rate for all additional consumption. If the second step is equated to marginal cost, it may result in an acceptable tradeoff between economic efficiency on the one hand and equity on the other. In practice, such a policy will obviously require special arrangements for cases such as the occupancy of large (single metered) apartment buildings occupied by many low income families; or bulk purchases by private water vendors whose customers are poor.

More complex tariff schedules with multiple increasing blocks or with blocks which are intended to increase approximately in proportion to the recorded income distribution of the country are also relatively common in developing countries. However, while they may often be the best that can be achieved in a political sense, they are not an entirely satisfactory solution. In many developing countries households with house connections represent a relatively wealthy segment of the population, and there is no good reason for pricing any portion of their consumption at less than marginal cost. There are also many influences on water consumption other than income, a reliable correlation between water consumption and household per capita income being particularly difficult to establish. If governments wish to redistribute income there are many more efficient ways to do it than through water supply tariffs. Given that since most water is consumed by a relatively small number of consumers a marginal cost-based price for all consumption over that required for basic health purposes would generally be an efficient, equitable, and financially viable policy.

Second-Best Issues and Shadow Pricing

Another difficulty encountered in applying marginal cost pricing to the provision of water supplies in known as the second-best problem. What may appear at first sight to be a step in the direction of economic efficiency (for example setting a price equal to marginal cost, or indeed, of introducing a pricing mechanism where none hitherto existed) may not be an improvement at all should inefficient conditions prevail in other sectors of the economy. Optimality in any one sector might require a price greater or less than marginal cost to counter such inefficiencies.

In practice, in any economy in which there is a reasonable degree of competition, it has to be assumed that elsewhere goods and services are sold at prices that in general approximate their marginal costs. If not, the difficulties of adjusting for all imperfections may lead to the conclusion that there are, after all, no empirical grounds for preferring any one set of pricing rules over any other. Where, however, goods or services that are in direct competition with (or are complementary to) the services in question are priced in a way that diverges sharply from the standard set for the water supply or sewage disposal system it may be possible to make the necessary adjustments. As noted earlier, if prices of resources employed in constructing and operating water supplies diverge from their marginal cost to society, shadow prices should ideally placed upon them in evaluating the real cost to society of the expenditure. Labor that would otherwise be unemployed might be valued near zero (that is, at an estimate of its opportunity cost) even though, due to market imperfection, it is able to command a wage rate in excess of the minimum amount needed to attract it; foreign exchange costs should be valued at their market rate; interest rates should reflect the social opportunity cost of capital, and so on. Adjustments of this nature are necessary if the ultimate consumer is to be faced with a price for water that reflects the true economic cost which his consumption entails.

However, such adjustments may not be sufficient. It may not be feasible (or economically efficient) to expect consumers to pay the full MOC for water if their own incomes do not adequately reflect social opportunity costs. This situation is clearly illustrated in economies that are undergoing radical restructuring, such as China. In fact, economic development in China is characterized by great unevenness; rapid liberalization in some parts of economy is not matched by equivalent changes in other parts. This is illustrated by the case of private abstraction of water by farmers. In the Beijing area, the bulk of the water consumed is privately abstracted by farmers and industry using private tubewells, such abstraction placing great pressure on dwindling groundwater sources, and necessitating the major investments in additional capacity referred to earlier. Private abstraction is virtually free of charge; raising price to MOC would doubtless reduce demand significantly, thereby enabling deferment of the water transfer scheme, and resulting in large net benefits.

Such reform may however be frustrated by the fact that farmers may be unable to pay a price for water equal to its MOC where price controls exist on farm products, or where production quotas exist. Similarly, industrial enterprises may be precluded from operating efficiently by a variety of government price controls, limited access to credit and other restrictions. Apart from purely political obstacles, distortions elsewhere in the system are therefore serious constraints to policy reform in any sector such as water supply. Thus the need to subsidize farmers is part of a much wider problem regarding agriculture price reform. However, it is important for policy makers to be made aware of the true extent of the magnitude of the subsidy that is provided to farmers and industrialists through allowing them access to free water supplies, so that the merits of such subsidies can be explicitly considered. As interim measures during the period of economic transition, alternatives might include marginal cost pricing for water plus a cash subsidy unrelated to water use; or compensation for reduction or closure of farm or industrial operations when the social costs of such operations clearly exceed the social benefits. The general conclusion is therefore that distributional equity as well as efficiency and fiscal considerations suggest that improved pricing for water and other public services - or for degradation of the natural environment - must be introduced gradually, in accordance with overall trends in market reform. A long term strategy is thus required.

D. CONCLUSIONS

While there are a number of complications, there is clearly considerable scope for water pricing reform in most developing countries. While some will gain and others lose from such reform, measures can be taken to protect deserving cases. However, from a societal point of view, price reform can be expected to be a "win-win" policy, i.e. in which various objectives can be satisfied at once. MOC pricing clearly has a role to play, but as the preceding pages indicate, its actual implementation requires much research, primarily of an empirical nature. Some of these are listed below:

(a) Identify the least social cost means of meeting projected water demand. The water supply and associated wastewater disposal program for a large metropolitan area might be selected for empirical study. Proposed engineering solutions could be evaluated, substituting economic for financial costs; alternative solutions, explicitly considering costs incurred, not simply by water authorities, but also by households, industry, and agriculture. The concept of opportunity cost, including the value of water in alternative uses, should be central to this analysis. External costs of water production and disposal) should also be explicitly considered. Note that in many cases, available engineering feasibility studies often relate to a fairly short time horizon, and are typically tied to preconceived engineering solutions.

(b) Related to the above, analyze the obstacles to implementation of socially cost-effective solutions; why are low cost technologies not implemented? Obstacles include price distortions, i.e. a divergence between social costs and the costs faced by the decision maker; these may be due to general market distortions, requiring shadow pricing adjustments to be made, or may be specific to the investment in question. Local distortions in labor and land markets, administrative and social problems associated with labor intensive or community based approaches; social and cultural constraints of various kinds may all conspire to prevent the implementation of socially cost-effective measures.

(c) Although MOC pricing is essentially used to place the burden of valuation upon the consumer, there is no escape from benefit measurement if the MUC and MEC components are to be evaluated. Moreover, knowledge of price elasticities, as noted above, will assist in system planning. There is considerable scope for applied research in this area. While a substantial body of experience exists, application and adaptation of standard methodologies to developing country situations is still required. Such research might include the following kinds of approaches:

    - measurement of the impact on property values (water, sewerage and drainage),
    - estimation of consumer surplus on the basis of expenditures that would otherwise be incurred on private means of waste disposal (septic tanks, etc.),
    - quantification of costs of travelling to existing water sources,
    - quantification of health benefits (water and sewerage),
    - estimation of consumer surplus from evidence of payments to water vendors, or planned investments in private sources of supply,
    - quantification of irrigation benefits (sewerage),
    - savings in costs of night soil collection (sewerage),
    - estimation of benefits for tourism and fishing (water and sewerage),
    - estimation of flood control benefits (sewerage),
    - contingent valuation approaches.

(d) Econometric demand analysis, using cross-sectional and/or time series data. Empirical analysis would involve, inter alia, data on water consumption by different income groups and types of industry. Relationships between water consumption and types of housing, quality of service, and means of wastewater disposal may also be assessed (e.g. inhabitants of single family dwellings can be expected to use more water than apartment dwellers; where water quality is inferior or shortages occur, supply considerations may dominate; water consumption is much lower for those relying upon public standposts or who are not served with adequate sewerage or other means of wastewater disposal.

(e) Estimate and recommend an implementation strategy for MOC pricing for water and its disposal in an urban metropolitan or a rural area. This should involve a sequence of estimates: least social cost solution; MOC calculation, including the AIC approximation to long run marginal cost; and implementation issues, including metering, financial and fiscal matters, provision of service to the poor, etc. Individual components of this exercise may also be identified as separate research topics, some possibilities being listed in (f) to (j) below.

(f) The metering decision. The importance of this topic is that it raises issues of a generic nature, and particularly relevant for environmental issues generally, in which problems may arise because the cost of ensuring and measuring exclusive use of a resource are very high. Such study should assess the costs and benefits of introducing water meters, the sensitivity to different assumptions about price and income demand elasticities as well as the costs of metering and the investment and operating costs of future water supplies. Consumers should be divided into groups, based upon the cost of metering and consumption levels, and the quality of wastewater discharged, and a determination made about the desirability of introducing metering - and its optimal timing - by consumer group. Where the costs of metering exceed the benefits, alternatives may be considered, and similarly subjected to cost-benefit analysis. This would be particularly important where metering is not feasible, and therefore where prices cannot be raised to ration capacity. In such cases water shortages have to be handled by physical rationing, which may take many forms, including cutting off supplies at certain hours. This may entail health and other costs; alternatively, flow control devices and design standards for water using appliances may be employed. Research should also consider alternative revenue raising methods in light of various criteria including efficiency; equity; and administrative feasibility.

(g) Second-best issues. The introduction of efficient pricing for water may be affected by the presence of general distortions in the economic system. Research on a strategy for implementing MOC pricing could involve a careful analysis of the prices of goods and services that are complementary to or competitive with water. In practice, this might be most useful in an economy in a major stage of transition such as China, where for example price reform applied to farm consumption might be frustrated by distortions in the prices of farm outputs.

(h) Pricing for wastewater disposal raises a series of researchable issues. Justification for investment in sewerage and sewage treatment should be based upon the MEC incurred if no such facilities exist. By case study, research should develop the criteria for extending sewerage facilities throughout a metropolitan area, and the appropriate charging system that should apply, both for those actually connected to the sewerage system as well as for those who are not. Such research should distinguish between dischargers of waste based upon the quality of their effluents and water pricing schedules developed accordingly. Since using water consumption as a basis for pricing is a rather blunt instrument, regulatory procedures are in practice the principal control method. However, there remains much scope for applied research regarding the appropriate mix of pricing and regulatory methods.

(i) Price variation according to time and location of consumption should also be analyzed. The case for seasonal peak load pricing in a number of different types of water resource systems, including those in which there are competing demands, i.e. for irrigation, hydroelectric power, or flood control systems should be assessed. More generally, the MOC of municipal water supply should be analyzed in terms of the opportunity cost in such alternative uses. The scope for varying price within a water utility's network may also warrant research.

(j) Financial and fiscal issues. Analysis of the financial and fiscal implications of MOC pricing is an important research topic. Increasing costs of water supply suggest that the issue will often be how best to dispose of excess profits. In this analysis, the prospects of using the revenues to expand service to low income groups, possibly accompanied by a "lifeline rate" for small users should be assessed. Alternatively, the case for using water revenues as a source of general revenue, and the mechanisms necessary to achieve this, should be considered. While increasing long run marginal costs of water may indicate financial profitability, this may be more than offset when marginal waste disposal costs are included, particularly if large scale rehabilitation works are required. Research should also include design of tariff structures in such cases.

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