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Satisfying Urban Thirst

Water Supply Augmentation and Pricing Policy in Hyderabad City, India

R. Maria Saleth
Ariel Dinar

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FOREWORD

The intense competition for water between various sectors that results from population growth, area expansion, and life style changes, may affect various decisions associated with water allocation and long-term investments. Water scarcity is likely to continue to be a major problem for many cities in developing, as well as developed countries. Conventional solutions of supply augmentation or administrative transfer of water between sectors may not always provide sustainable solutions to the problem.

This paper suggests a framework of intra-sectoral water transfer. This framework which is based on proper water pricing scheme induces water savings under severe water scarcity situations in urban centers. Such framework might be preferable to a more costly supply augmentation and institutionally-complicated inter-sectoral (agricultural-urban) alternatives.

Through the case study of Hyderabad, the paper provides a general framework for evaluating the effectiveness of water pricing that can be applied to other urban centers in the world.

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ABSTRACT

The customary practice of meeting urban water deficit through supply augmentation by tapping distant and multiple-use water sources often disturbs prevailing sectoral allocation and causes inter-sectoral water conflicts. The common prescription for resolving such conflicts involves market-based approach to inter-sectoral water allocation. Under conditions of an uneconomic rate structure and pervasive use inefficiency and wastage in the urban water sector, inter-sectoral water transfers--whether market-based or otherwise--are likely to conceal inefficiency, damage incentive structure, and dampen the urge to explore supply augmentation options evident within current urban supply limits.

Utilizing both primary and secondary information pertaining to the water sector of Hyderabad city, India, this paper investigates the kind of policy changes and institutional conditions necessary to ensure the economic viability of market-based solution to inter-sectoral allocation problems in an urban context. This is done by (a) evaluating the economics of various supply augmentation options--both internal and external as well as structured and unstructured, (b) estimating the user-specific water demand and consumption response functions under alternative pricing (average and marginal) schemes, (c) calculating the net willingness to pay (NWTP)--considered to be an approximation of the value of raw water--of user groups from their respective price elasticities, (d) demonstrating how inadequate the NWTP is to justify most supply augmentation options including inter-sectoral water transfers, and (e) arguing that the economic conditions internal to the urban water sector can never support an externally imposed water transfer--whether market-based or otherwise--as long as the rate structure is low and uneconomical.

The main implication of this paper is that although local level supply augmentation options cannot, by themselves, solve urban water deficit altogether, their exhaustion is admittedly a necessary condition for market-based inter-sectoral water transfers to be free of the damage to the incentive environment facing urban water sector. Both to fully exhaust local level options and to economically justify macro level options, setting urban water sector right with proper pricing policy and legal and institutional changes is obviously the first reform task.

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EXECUTIVE SUMMARY

The customary practice of meeting urban water deficit through supply augmentation by tapping new, distant, and multiple-use water sources often disturbs sectoral allocation and causes inter-sectoral water conflicts. The common prescription for resolving such conflicts involves market-based approach to inter-sectoral water allocation. With an uneconomic rate structure and pervasive use inefficiency and wastage in the urban water sector, inter-sectoral water transfers--whether market-based or otherwise--are likely to conceal inefficiency, damage incentive structure, and dampen the urge to explore supply augmentation options evident within current urban supply limits.

Keeping the fact noted above as an underlying theme and utilizing both primary and secondary information pertaining to the water sector of Hyderabad, this paper attempts to: (a) evaluate the economics of various supply augmentation options--both internal and external as well as structured and unstructured and (b) investigate the kind of economic and institutional changes needed to actualize these options with the help of empirically estimated group-specific residential water demand functions.

The water sector of Hyderabad, the capital of Andhra Pradesh, India presents not only problems typical of many other cities but also solutions common to most urban centers in India and elsewhere. With the geographic coverage of 1547 sq.km. and a population of about 4.35 million displaying an annual growth rate of 2.17 percent, the gross annual water demand for the city is projected to triple from 362 million cubic meter (mcm) in 1991 to 1013 mcm by 2021. Against this growing demand, the net water supply (i.e., excluding leakages and losses) from the six supply sources developed till 1994 is only 206 mcm giving rise to a 40 percent deficit in net demand. Although the deficit is expected to be gradually eliminated with the proposed inter-basin water transfers from Krishna and Godavari rivers by 2021, it will continue to be a serious problem in the meantime.

Notably, the water losses in the treatment and distribution stages amounting to 50 percent of net demand deficit at present is expected to account for 82 and 67 percent of the same by 2001 and 2011 respectively. If the total water loss at the system as a whole is reckoned, it will certainly be close to, if not exceed, both the observed and projected demand deficits. This underlines the vast scope for deficit reduction present even within the existing supply limits partly by improving use efficiency and conservation and partly by activating micro level supply augmentation options. But, the economic environment facing the city's water supply system at present remains rather unfavorable for deficit reduction through these desirable means.

The cost recovery that has remained at 100 percent or above till 1993-94 has declined to 88 percent by 1994-95. In the face of a six-fold increase in the average supply cost of metro water (i.e., from Rs. 0.88 to 5.58/cum) during 1989-95, the average water charge continues to remain at about Rs. 3.62/cum since 1993. The long-run average and marginal cost curves constructed for the city's water supply system reveal that the average cost declines with supply whereas the marginal cost, though declines with supply up to 315 cum, rises at an increasing rate beyond that supply level. Besides, since both costs are higher than their revenue counterparts, the water supply system is likely to encounter a serious financial crisis in the near future unless the water rate structure is revised to fully reflect the economic realities.

Contrary to conservation requirements, under the present block rate structure, the water rates are not only lower than supply cost but also biased in favor of larger consumers. Moreover, the price perception that the rate structure generates among users is conducive neither for providing incentives of the magnitude needed activating various micro level supply augmentation

nor for justifying macro level supply augmentation options involving large scale inter-basin water transfers.

Supply augmentation options--both at the system and at the user level--are important to minimize the effects of water deficit. At the system level, besides the options centered on system strengthening and rehabilitation as well as the Krishna and Godavari schemes, the water deficit is also managed by interim policies involving a combination of supply hour manipulation and differential inter-city water allocation. Although the average supply hours for the city is 3 hours/day (expected to be 6-7 hours/day after 2001 with Krishna water transfers), it is not uniform throughout the city.

Among uses, the industrial water demand is fully met whereas the residential demand is met only partially. Across regions, while net allocation covers 64 percent of net demand in the Municipal Corporation of Hyderabad (MCH) area, it covers only 28 percent of the same in the non-MCH area. Notably, this unequal water allocation pattern is expected to continue till 2021 notwithstanding supply augmentation in the meantime.

At the micro level, consumers--both domestic and non-domestic--adjust with water deficit at their end by relying on a variety of supply augmentation options depending upon their economic capacity. These options range from investment in in-house storage to the installation of own wells. Other options which are either partially adopted or potentially adoptable are: water purchase from private tankers, privately organized small scale water transfer from irrigation, joint supply arrangements by neighborhood groups, and inter-household water sharing including local water markets. These options with differential institutional implications and feasibility status, though can be substitutes at the user-end, are really complementary at the system level as they have to be simultaneously relied on for deficit reduction.

The unit cost estimates for an identified set of 11 options range from Rs. 0.55 to 62.50/cum defining not only the feasible economic range for various forms of micro and macro level water transfers but also for fixing urban water charges at economic levels. Given the metro water supply cost of Rs. 5.58/cum, water diversion from irrigation--organized on either public or private account--with a unit cost of Rs. 2.95 to 3.50/cum can be economical even when Rs. 1.00/cum is added as the cost for transmission, treatment, and distribution. Similarly, the vast cost differentials between groundwater use by household groups (Rs. 0.55/cum) and that by individual households (Rs. 6.61/cum) indicate the economic scope for the emergence of novel institutional arrangements involving joint supply and inter-household water sharing within a given locality.

Since the economic feasibility of these options depends critically on the prevailing water rate structure and the price perception that it generates, urban water pricing plays a central role in activating the whole spectrum of supply augmentation options available both at the system and at the user levels. The centrality of pricing option is empirically demonstrated with the help of econometrically derived water demand functions estimated under different pricing behaviors and various estimation contexts defined by consumption brackets and housing categories.

In an attempt to resolve the two controversies, i.e., the average price vs. marginal price and the econometric question of simultaneity bias, that overwhelm the residential water demand literature, this study uses a methodology that not only admits the analytical relevance of both prices but also permits the endogenization of the simultaneity issue within the demand model itself. As a result, unlike many past studies, the present one can address the role of price perception simultaneously with the role of the price structure. The methodology accomplishes this by comparing demand functions under the two pricing behaviors on the one hand and by evaluating the consumption response function that captures the sensitivity of consumption change to price switch on the other hand. The economic scope for the supply augmentation options within the existing rate structure is also empirically evaluated using consumers' willingness to pay derived from demand estimates.

The regression results of water demand functions (with a log-log form) estimated under the two pricing schemes show that even though the mean marginal price (Rs. 3.95/cum) is not different much from the mean average price (Rs. 3.62/cum), effecting marginal pricing behavior could radically alter consumption behavior even within the existing water rate structure. The price coefficient that remained mostly positive under average pricing becomes negative and significant with marginal pricing in all contexts. The price elasticity under marginal pricing is 0.58 for the sample as a whole but varies considerably across consumption brackets (0.47 to 5.34) and housing categories (0.49 to 0.72).

The overall inelastic nature of demand, especially among groups with the necessary capacity for investing in alternative supply augmentation options, however, reduces their adoption prospects because the price switch-induced price increase is lower than the cost of most options. Even though the real scope for adopting direct supply augmentation options is limited, the price switch can, nevertheless, induce the adoption of indirect options like cutting down non-essential uses or minimizing in-house water wastage/loss. The real scope for direct supply augmentation options, therefore, depends less on the price switch (or change in pricing behavior) per se but more on the level of price increase and the economic ability of consumers to adjust their consumption within the supply limits evident at their end.

Regarding the level of price hike needed to make water consumption sensitive to price switch, the estimates of consumption response functions (with a log-log from) show that a given change in metro water consumption requires, in general, more than proportionate change in price. For the sample as a whole, a point reduction in metro water consumption requires 1.70 point increase in water rates. However, among users with larger consumption, a given change in consumption can be achieved with a less than proportionate change (0.88) in price levels.

Although the metro water consumption of larger consumers and economically well endowed households can be influenced with a price hike far lower than that needed for others, it is not explicit whether the level of price hike implied by the response function estimates will be (a) strong enough to economically activate the alternative supply augmentation options and (b) within the acceptable range for consumers. The answer requires an explicit consideration of users' net willingness to pay (NWTP).

The NWTP or consumer surplus/cum not only shows the extent price can be hiked but also approximates the value of raw water under the existing water rate structure. The NWTP is influenced by three factors, i.e., price elasticity, the extent of consumption reduction, and the water rate structure. Depending upon these factors, the NWTP calculated under marginal pricing varies from Rs. 0.09 to Rs. 2.20/cum whereas the same under the average pricing varies from Rs. 0.01 to 2.22/cum. While marginal pricing does lead to higher NWTP as compared to average pricing among consumers of all types, the resultant increase in NWTP is far lower than the cost of most supply augmentation options. Thus, the ability of a mere price switch or change in price perception as an incentive mechanism for enhancing the adoption prospects of supply augmentation options is extremely limited.

Clearly, the proposed inter-basin water transfers from Krishna and Godavari rivers with a raw water cost Rs. 2.29 to 4.40/cum cannot be economically justified without a substantial upward revision in current water rate structure. In contrast, since the option involving joint groundwater use has an unit cost of Rs. 0.55/cum, there is considerable incentive even now for joint initiatives in local supply augmentation including inter-household water exchanges. The potential for the evolution of urban water institutions like informal water user groups, water sharing grids, and urban water markets can be enhanced further with an economically rooted urban water pricing policy coupled with an intensive extension program and a legal and institutional environment facilitative of users' participation both in supply augmentation and management.

Although local level supply augmentation options cannot, by themselves, solve urban water deficit altogether, their exhaustion is admittedly a necessary condition for bringing additional water from inter-basin transfers without a damage to the incentive environment facing urban water sector. Both to fully exhaust local level options and to economically justify macro level options, setting urban water sector right with proper pricing policy and legal and institutional changes is obviously the first reform task. While myopic political economy considerations do delay urban water sector reform, the economic fallout of the brewing financial crisis on the one side and the equally serious political fallout of the growing inter-sectoral water conflicts clearly point to the economic and political advantages in undertaking the policy reforms immediately rather than postponing them indefinitely into the future.

INTRODUCTION

With urban expansion, population growth, and life style changes, urban water needs are likely to surpass supply availability from usual sources. Most urban water supply authorities prefer to respond to this demand deficit problem by augmenting existing supply via tapping new, distant, and often costlier water sources. Under conditions of an overall water scarcity where the water demands of non-urban sectors are also growing concurrently, such supply augmentation attempts can create serious inter-sectoral water allocation conflicts. Although political economy considerations and ethical/legal protection for drinking water often resolve such conflicts in favor of the urban sector, there are obvious limits to this policy as it cannot remain immune for ever from the political economy repercussions of regular infringement of prevailing sectoral allocations.

Under such circumstances, advocates for efficient water allocation and use suggest the market-based approach as a permanent solution to the inter-sectoral water conflicts. Since water is expected to be transferred from less efficient (low value) uses in irrigated agriculture to more efficient (high value) use in urban centers with appropriate compensation by the buyers to the sellers, the market solution to inter-sectoral water allocation problem is considered to be mutually beneficial and hence, agreeable to all concerned.

Although the market approach is theoretically sound and also preferable as a long-term solution, the potential for the violation of several assumptions implicit in this approach minimizes both its relevance and practicability as an immediate and universal solution. First, urban water use is assumed to have attained its full efficiency level and that the sector has already exhausted all possible options for supply augmentation available within the existing supply limits. Second, the conveyance and treatment costs related to the transferred water are heavily underestimated. Third, the market price for such water is considered to be lower (higher) enough to rest in the affordable (acceptable) range of the urban (non-urban) sector. And, finally but most importantly, the legal, institutional, and technical mechanisms necessary for the consummation of such inter-sectoral water transfers are either assumed to be already in place or expected to emerge within the prevailing socio-political and economic environment itself.

It is true that these assumptions can hold in well-established and institutionally and technically mature urban water supply systems with proper payment culture, this is not exactly the case in most urban centers in developing countries. Here, the typical urban water supply system is characterized by poor and unreliable water services, the predominance of unmetered connections, high levels of water loss in conveyance/distribution and use inefficiency at the user-end, low and biased tariff structure with an inherent cross subsidization between users and sub-sectors, and low water charge recovery.

In this situation, the policy of supply augmentation through inter-sectoral water transfers--whether market-based or otherwise--is likely to conceal the current levels of inefficiency and wastage evident in the urban water supply system. In so far as such water transfers are not financed by internal resources especially from increased water charges, they remain devoid of their usual incentive properties so crucial for inducing both the urban water supply agencies as well as the urban consumers to augment their water supply through efficiency enhancement and conservation initiatives.

Since a mere supply-side solution to urban water scarcity creates an economic environment inimical for the emergence and growth of new institutions and innovative practices, it undermines the urge to search for more durable demand-side solutions. As a result of this economic vacuum, many feasible options--both technical and institutional--for realizing the hidden water potential available within the existing levels of urban water supply remain unexplored and unexploited. Obviously, the economic justification for market-based inter-sectoral water transfers, as a preferred and durable solution to urban water deficit, is critically predicated on suitable changes in the economic and institutional environment indispensable to create the incentive conditions for use efficiency and conservation and realize, thereby, the hidden supply potential.

In the absence of changes directed to enhance the value of water in the perception of urban users and encourage, thereby, the fuller exploitation of micro level supply augmentation options available within the existing supply limits, neither there will be an economic justification for inter-sectoral water transfers nor will there be the conditions in which the users could accept a higher water payment associated with such costly water transfers. Keeping this point as an underlying theme and considering Hyderabad as a typical city in developing countries, this paper aims to investigate the urban water supply situation that most urban centers in the developing world are facing, how they could amend their water deficits by exploiting both the internal and external structured and unstructured possibilities for supply augmentation, and indicate the kind of economic and institutional changes which are needed to economically activate these supply augmentation options.

More specifically, this paper makes an attempt to (a) gauge the real magnitude of the water deficit problem in Hyderabad based on a critical review of current and projected water demand and supply levels, (b) evaluate the economic aspects and feasibility status of alternative supply augmentation options, (c) demonstrate the perverse effects of the existing price structure and how such effects could be eliminated by a switch to an alternative pricing scheme using empirically estimated domestic water demand functions across various consumption and housing categories, and (d) indicate the central role that the pricing option plays not only in activating a number of non-price options but also in generating incentives for the emergence of new and the consolidation of the already existing institutional mechanisms so crucial for actualising economically motivated water transfers and conservation initiatives.

THE EMPIRICAL SETTING

Hyderabad, the state capital of Andhra Pradesh, is one of among the fast growing urban conglomerations in India.. Being a typical inland city located in the south-eastern part of the Deccan plateau with an arid climate and insufficient rainfall, the water situation of Hyderabad presents both problems typical of many other cities as well as solutions common to most urban centres both in India and elsewhere. Like most urban centres, water scarcity has become one of the most serious constraints for the expansion and growth of Greater Hyderabad, covering the twin city of Hyderabad and Secunderabad as well as many surrounding municipalities and villages. Obviously, the identification and evaluation of alternative economic options for augmenting urban water supply constitute a central component of urban planning and infrastructure management. Both the individual and relative significance of these supply augmentation options as a means for reducing the city's water deficit can become more transparent when the exercise of their identification and evaluation is preceded with a brisk description of the major physical and economic features of the Hyderabad urban water supply system.

Water Requirements

The aggregate water requirements for a city is determined, in general, by its geographic coverage, residential land use, population growth and density, and the level of commercial and industrial development. The present coverage of the Hyderabad Urban Development Authority (HUDA) area is 1547 sq. km. which includes the Municipal Corporation of Hyderabad (MCH), adjoining nine municipalities, Osmania University and Secunderabad cantonment, and surrounding urban, semi-urban, and rural areas. Of the HUDA area of 1547 sq. km., the service area of the Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) covers 707 sq. km. with a future plan for adding an additional area of 46.30 sq. km. The residential land use for the MCH area has increased from 13.8 percent in 1965 to 24.1 percent in 1981. While the residential land use proposed by HUDA for 1991 is 45 percent, it is projected to be 50 percent for 2021.

The population of the service area observed to be 4.35 million in the 1991 Census is projected to be 8.19 million in 2011 and 10.15 million in 2021 implying an annual growth rate of 2.17 and 2.77 percent respectively during the two decades (see Table A1). Notably, the municipalities are expected to grow much faster and hence, will have an increasing share in total population.

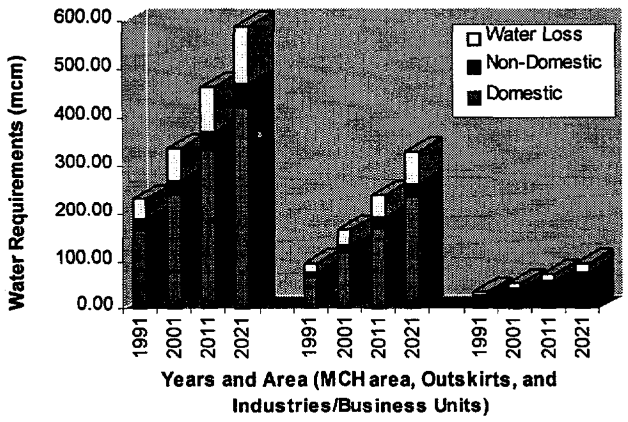

Figure 1

Water Requirements by Regions and Uses, Hyderabad, 1991-2021

Source: Authors' calculations

Given the service area, residential land use, and population density and growth, the water requirement for various urban purposes has been estimated using unit water requirement norms.[1] While this procedure helps in estimating total net water requirement (i.e., at the consumers' end), the estimation of total gross water requirement (i.e., at the supply source) involves consideration related to water loss both at the treatment and distribution stages. Although leakage detection surveys conducted during 1992-94 reveal the average rate of leakage to be 140 litres/connection/hour, in its estimation of both current and future gross water demand (i.e., net water demand plus leakage loss), the HMWSSB assumes a fixed leakage loss of just 20 percent of net water demand (HMWSSB, 1993:2 and 1995b:5). Although the demand projection beyond 2000 also presumes a 5 percent increase in demand due to changes in life style (HMWSSB, 1995b:51), the allowance made for the qualitative or structural changes in water consumption pattern is obviously very modest.

The gross annual water demand for the service area is projected to triple from 362 million cubic meter (mcm) in 1991 to 1013 mcm in 2021 (see Table A3). Figure 1 shows the regional and use category-wise composition of the projected gross requirements. Across regions, although the MCH area continues to have a dominant share in total demand, its share is expected to decline from 64 percent in 1991 to 58 percent in 2021 whereas the share of municipalities is projected to improve

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[1] These norms are established using either consumption surveys, ledger records, or standards set by specialised agencies. The norms underlying the unit water requirement of various uses are given in Table A2.

from 23 to 30 percent during the same period. This regional shift in water demand is partially a reflection of the faster population growth expected to occur in the non-MCH area.

Against this substantial shift in the regional pattern in water demand, theuse category-wise composition of water demand is expected to remain the same both across regions and time points. Domestic uses will continue to account for 64 percent of gross demand but 88 percent of net demand. The most notable aspect here is that the unaccounted for water (i.e., leakage/distribution losses) representing 20 percent of the gross water demand (even with leakage control program) is much more than the total non-domestic water demand.

Water Supply

Table 1 presents the crucial technical features of the existing sources of water supply that the city will rely on till 2001. Although the combined storage capacity of the system is 375 mcm, the nominal yield is only 273 mcm. There are 9 water treatment plants with a treatment capacity close to the total nominal yield. Water distribution is done through transmission mains with a total length of 286 km and 122 service reservoirs located in different parts of the city. While the distribution system is essentially gravity-based, pumping is, however, needed in 25 stations located both in the trunk and local distribution systems.

The pattern of water source development in Hyderabad during 1922-1994 reveals three important aspects. First, the time gap between successive projects especially after 1927 declines steeply suggesting the urgency of supply augmentation to keep pace with the growing urban demand. Second, since the distance of the water source from the city is increasing with each new project, not only the cost but also distribution and transmission losses have become increasingly higher. Third, unlike the first two sources that involve essentially water diversion from tanks (i.e., large ponds) located within the city limits, the recent projects rely on direct diversion from rivers through barrages and dams located far away from the city. As such, apart from the cost and water loss implications, the increasing reliance on distant and multiple-use water sources creates eventually, if not now, the potential for inter-sectoral water conflicts. The intensity of these inter-sectoral conflicts will be more severe when the

Table 1. Technical Features of Existing Water Supply Sources, Hyderabad.

Source	Osman Sagar	Himayat Sagar	Manjira Phase-I	Manjira Phase-II	Manjira Phase-III	Manjira Phase-IV
Year of Commissioning	1922	1927	1965	1981	1991	1994
River	Musi	Esi	Manjira	Manjira	Manjira	Manjira
Impoundment Name	Osman Sagar	Himayat Sagar	Manjira Barrage	Manjira Barrage	Singur Dam	Singur Dam
Catchment (sq. km)	738	1311	673	673	16770	16770
Storage Capacity (mcm)	124.6	104.8	42.5	42.5	30	30
Distance from City (km)	15	8.6	58	59	80	80
Type of System	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity
Treatment Capacity (mcm)	45	33	30	55	55	55
Nominal Source Yield (mcm)	42	33	30	55	55	55

Source: HMWSSB (1995b:20).

proposed long-distance inter-basin water transfers from Krishna and Godavari Rivers are undertaken to augment the city's water supply beyond 2001.

The most serious problem with the existing water supply system is its poor physical health and the attendant operational inefficiency. For example, in the case of both Osman Sagar and Himayat Sagar accounting together for 60 percent of the total storage and 28 percent of total nominal yield of the existing water sources, not only the reliability of water withdrawal has declined considerably but also there has been a loss of gross storage capacity mainly due to siltation.[2] Since some of the components of the system are in service since the 1920s, the system requires a major rehabilitation and strengthening program even to maintain the existing water supply level.[3] This means that along with supply augmentation through water transfer from Krishna and Godavari Rivers, a massive rehabilitation and strengthening program costing Rs. 7.3 billion (Rs. 35.18 = US$1 in 1995) has also to be urgently implemented so as to improve the existing storage, treatment, and distribution networks.

As to supply prospects from additional sources to be taped beyond 2001, while Krishna water will be brought in three phases (corresponding to the years 2001, 2011, and 2021)--each with an annual delivery of 117 mcm, the Godavari scheme expected to commence by 2021 will add 296 mcm to the system so as to meet the entire water deficit expected to prevail then. These proposed inter-basin water transfer schemes are expected to add 600 mcm of net water supply (i.e., excluding treatment and distribution losses) to the existing supply of 206 mcm (see Table A4).

Despite the massiveness of the inter-basin water transfer schemes, the distribution loss is assumed to decline from 20 percent at present to 16 percent after 2001. This is in contrast to the reality of increasing distribution loss partly due to the direct relationship that distribution loss has with both the amount of water being distributed as well as the conveyance distance and partly due to the acknowledged ineffectiveness of leakage control program beyond the main trunk lines. While the need to tap additional sources is inevitable given the fast growing demand, the massiveness of supply addition planned under these schemes could not only cause a heavy strain on the already inefficient transmission and distribution networks but also damage the already fragile incentive environment.

Finally, it needs noting that the water supply projections discussed so far are based only on surface water because groundwater sources are not expected to add much to the supply. It is estimated that groundwater within the city can meet no more than just 6 percent of the total water demand by 2021 and this source can, at best, only supplement the surface water supplied through the metro water supply system (HMWSSB, 1995b:5).[4] Although cost and water quality

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[2] An analysis of reliable yield from these two impoundments indicates that it is possible to draw only 27 mcm and 24 mcm, respectively (at 99 percent level of confidence) as against the corresponding average yield of 42 mcm and 33 mcm expected from these two sources (HMWSSB, 1995b:5). Similarly, an area-capacity survey reveals that during 1973-88, the gross storage for Osman Sagar has declined by 12 percent and that for Himayat Sagar has declined by 20 percent (HMWSSB, 1995b:79).

[3] A study commissioned by the HMWSSB (1995b) recommends, among other things, the need for an addition of 27 pumping stations besides the rehabilitation of existing pumping stations, an addition of 24 service reservoirs and 3 sumps for pumping water, and the re-organization of the existing 18 water distribution zones into 20 zones for better inter-zonal water allocation and management. Moreover, there is also the need to replace 20,250 service connections, transfer 19,000 spaghetti connections, and repair 64,000 leak points.

[4] Besides, the groundwater situation in the city is not very comfortable. For instance, an analysis of water table fluctuations in 24 borewells located in different parts of the city during 1987-92 shows that the dif-

considerations do not favour groundwater as an exclusive source for all uses, its role as a supplementary and stand-by source cannot, however, be ignored completely especially when metro supply becomes inadequate or unreliable.

The Demand-Supply Gap

The extent of water deficit in a given city is usually captured by the magnitude of demand-supply gap. The extent of water deficit as defined by the demand-supply gap can be used to indicate the degree of water scarcity prevailing in the city. When the water deficit is considered on a net basis by isolating water loss/wastage occurring both at the distribution and consumption stages, it can capture the real as opposed to the nominal degree of water scarcity present in the system. By relating the net water deficit with the level of water loss, it is also possible to show the extent waste minimization and other water conservation initiatives could solve the water deficit and water scarcity problems.

As can be seen from Table 2, the actually observed net water deficit is substantial and showing a rising trend. Although the deficit is expected to be eliminated by 2021 especially through large-scale inter-basin water transfers from Krishna and Godavari Rivers, it will continue to be a serious problem till the materialization of these water transfer schemes. The deficit that accounted for 40 percent of net demand in 1991 has risen to 44 percent in 1996 but expected to fall to 25 percent by 2001.

Table 2. Water Supply Situation, Metropolitan Hyderabad, 1991-2021.

Year	Net Demand (mcm/year)	Net Supply (mcm/year)	Deficit[a] (mcm/year)	Deficit as % of Net Demand	Water Loss (mcm/year)	Water Loss as % of Deficit
1991	263.53	159.10	102.77	40	52.70	51
1994[b]	333.25	198.56	134.69	40	66.57	49
1996	367.19	206.22	160.97	44	67.53	42
2001	443.84	332.88	110.96	25	90.52	82
2011	621.60	472.31	149.29	25	100.74	67
2021	810.30	810.30	0.00	0	230.68	-
MCH at Saturation[c]	861.77	861.77	0.00	0	240.90	-

[a] Includes losses both at treatment and distribution stages. Of this, distribution losses alone account for over 60 percent.

[b] The water need figure is based on an expanded area coverage of the service area that covers almost the whole HUDA area (see Table A1).

[c] Relates to the full development of the city with population stabilizing around 10.45 million. These figures are obtained from all the reports of the Hyderabad Water Supply Corporation cited in this paper.

Source: HMWSSB (1995b:5).

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ference between the pre-monsoon and post-monsoon depths in most of them has declined continuously suggesting clearly a secular decline in ground water table in the HUDA area. The depth of these borewells varies from 21 to 55 m with an yield range of 0.9 to 30 cum/hour (see HMWSSB, 1995b:219-224).

What is notable the most is the fact that water deficit continues to coexist with the perennial problem of water loss. While water loss cannot be eliminated altogether especially in a system involving a geographically widespread transmission and distribution network, its magnitude in relation to the water deficit is one among the serious water management issues for cities like Hyderabad. The water loss which represented 51 percent of the actual water deficit in 1991 is expected to represent for 82 percent of the projected water deficit in 2001 and 67 percent of the same in 2011.[5]

If we add water loss and wastage occurring at the consumer's end with that in the treatment, transmission, and distribution networks, the total water loss within the supply system could be very close to, if not more than, the water deficit. The water loss of such a magnitude indicates the vast scope for substantial reduction in water deficit within the existing supply limits. Since water deficit cannot be eliminated only by water loss reduction due to the practical limits to such policy, supply augmentation through inter-basin water transfers are obviously inevitable. But, a mere super-imposition of a politically motivated--rather than an economically justified--water transfer option on an already inefficient supply system will not just conceal existing inefficiency but actually exacerbate the same.

The already lower incentives for efficient water use gets reduced further and the economic opportunities for meeting water deficit through demand management and water minimization are irrevocably lost for ever. Even though a physical equilibrium between water demand and supply can be achieved, its durability is in doubt as long as the water rate structure remains unrevised and water use inefficiency continues unabated. A purely physical solution devoid of the indispensable economic and institutional back-up could only be tentative and transitory. Unless the system is set right with the infusion of effective economic incentives, the supply augmentation through large scale water transfers will add more to the problem than to the solution both in the urban and general contexts.

There is also the justifiable doubt as to whether the city could actually achieve the expected demand-supply equilibrium even in an *ex ante* physical sense. Although the total water deficit is projected to be eliminated by 2021, its practicability is in doubt because of the incompleteness and bias inherent in both demand estimates and supply projections. Since the demand projections assume the continuation of the existing water use pattern and efficiency level, use the average values of unit water requirement rather than the actual consumption figures, and ignore the water loss/wastage at the end-user level, they suffer from substantial degree of downward bias. In contrast, the supply projections suffer from an upward bias as both future supply augmentations as well as the water supply capabilities of current sources are overestimated.[6]

Moreover, the realization of the projected supply depends on rather ambitious supply augmentation options involving financially demanding and legally sensitive inter-sectoral and inter-basin water transfer schemes. Although it is asserted that the entire demand deficit beyond

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[5] Notably, the water loss problem will continue to be as serious as ever even when water deficit is completely eliminated, as planned, by 2021 (see Table 2).

[6] Water supply from existing sources is likely to be lower than expected mainly due to their old structure, storage loss from siltation, etc. For example, while supply projections presume water supplies of 33 and 42 mcm respectively from the Himayat Sagar and Osman Sagar sources, the actual water withdrawals from these sources (at 99 percent confidence level) cannot exceed 24 and 27 mcm respectively. Besides, unlike the relatively more perennial Krishna and Godavari sources, the reliability of water supply from the existing sources depends crucially on the level and distribution of rainfall in their catchments.

2021 will be met by Godavari waters, it is not made clear how the radical reduction in water deficit and improvement in service time will be achieved. Since the zero water deficit expected to be realized after 2011 is linked to the materialisation of the supply targets set for the Krishna and Godavari waters, whatever the problems that affect the progress of these scheme will risk the deficit reduction target. In all probability, it is more than likely that substantial demand will remain unmet even after 2021.

Economic Environment

The economic environment of the city's water supply system can be captured in terms of the cost and revenue of the water supply agency on the one hand and the prevailing level and structure of water tariff on the other hand. Table 3 shows the trend in revenue and cost of the water supply agency during 1989-95. Although the cost recovery rate is kept at 100 percent or above in all years except 1994-95 where it was only 88 percent, the actual supply cost of metro water has increased over six-fold between 1989-90 and 1994-95.[7] There is also a notable change in the structure of cost where the share of power and maintenance components are increasing while that of staff component is declining. This means that with future supply augmentation through inter-basin transfers and the associated expansion of transmission and distribution networks, the share of water treatment and distribution costs (i.e., the power, chemicals, and maintenance costs) is likely to increase with every increase in total supply cost.

Table 3. Water Supply, Revenue, and Expenditures, Metropolitan Hyderabad, 1989-1995.

Year	Water Supplied (mcm/yr)	Total Cost (mill.Rs)	Pattern of Total Cost (%)					Revenue (mill. Rs)	Cost/cum (Rs)
			Power	Staff Cost	Chem -icals	Mainte -nance	Deprec -iation		
89-90	113.15	100	30	50	5	10	5	100	0.88
90-91	113.15	250	32	48	4	12	4	250	2.20
91-92	113.15	345	35	49	3	10	3	345	3.05
92-93	131.40	440	36	41	3	15	5	440	3.35
93-94	98.55	505	38	40	2	16	4	535	5.12
94-95	102.20	570	39	37	4	15	5	500	5.58

Source: HMWSSB (1995b).

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[7] While the revenue consists of mainly connection fees and water charges, the costs include operation and maintenance costs plus a notional depreciation. Obviously, the costs are only financial but not full economic costs.

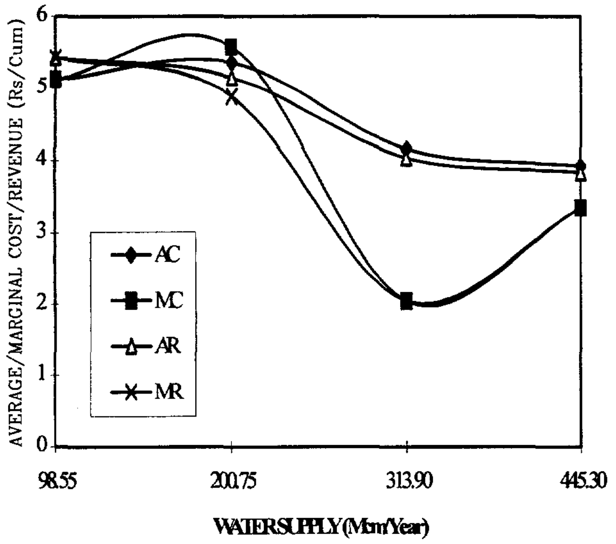

Figure 2

Long-RunAverage/Marginal Cost/Revenue, HMWSSB.

Source: Authors' calculations

The long-run average and marginal cost and revenue curves for the Hyderabad water supply system are depicted in Figure 2. Although the average cost will decline with supply augmentation, it is still higher than average revenue partly due to concurrent increase in water loss and partly due to lower water rates. It is indicative of a persistent revenue gap for the water supply agency. Notably, there is also a gap between marginal revenue and marginal cost at lower supply levels where both of them are falling, though at a differential rate. Although this gap will vanish when the supply exceeds 300 mcm, it is precisely at this stage that the marginal cost of water begin to rise suggesting clearly that additional water supplies are becoming costlier than before.

While the cost situation facing the system both at present and future is quite unfavorable, the revenue side is also very problematic. While grants and subsidy (especially through the provision of subsidized power, land, and buildings) from the state government and donor agencies often come to the rescue, from the point of view of creating an economically independent and functionally autonomous urban water supply institution, the dependence on such rescue operations can do more harm than good. In most cases, these grants and subsidies are, in fact, instrumental in perpetuating an uneconomic water rate structure that reflects neither costs nor the value of water. The water rate structure prevailing in Hyderabad (see Table 4) is not an exception to this phenomenon.

It can be seen from Table 4 that even though the slab-specific water rates are increasing at an increasing rate, the rate structure in the context of all use categories and application contexts are biased in favor of larger consumers due to the consumption slab structure where the gap between subsequent slabs increases at a much faster rate. This rate structure has the following effect. While consumers in higher slabs will be paying more than their counterparts in lower slabs, among consumers within the same slab, the change in average price/cum due to consumption increase, though positive, declines with consumption level. For instance, it can be verified from Table 4 that in the cases of consumption slab 25-500 cum, an increase in consumption from 30 to 40 cum causes the unit price to rise substantially from Rs. 3.16 to 3.63/cum whereas the same level of consumption increase at the higher range of the same slab, i.e., from 450 to 460 cum leads the price only to increase marginally from Rs. 4.87 to 4.88/cum. This means that although the average cost of water increase with consumption level, the incremental cost of adding consumption declines with consumption level.

Table 4. Structure of Water Supply Tariff, Hyderabad, 1993

Consumption Category	Consumption Slab (cum/month)	Rate (Rs/cum)
(A) DOMESTIC SUPPLIES **1. Individual Connections**		
(a) Unmetered Connections	Flat Rate/Month	120.00
(b) Metered Connections	Up to 15 (Rate/Month) 15 - 25 25 - 500 over 500	40.00 3.00 5.00 10.00
(c) Multi-storeyed Buildings Used for Domestic Purpose[a]	Minimum Rate/Month Up to 300 Over 300 Over 500	500.00 3.00 5.00 10.00
2. Bulk Supply		
(a) Enroute Areas along Manjira Pipeline	Full Quantity	2.00
(b) Other Villages & Towns	Full Quantity	3.00
(c) Housing Colonies	Up to 300 Over 300	3.25 5.75
For (a), (b), and (c)	Over 500	10.00
(B) NON-DOMESTIC SUPPLIES		
Industrial & Commercial Units[b]	Up to 50 50 - 500 500 - 1500 Over 1500	6.00 8.00 10.00 12.00
(C) OTHER SUPPLIES		
(1) Water Supply by Tankers	Per Tanker (5 cum)	100.00
(2) Temporary Connections for Functions, etc.	15 mm Connection/Day 25 mm Connection/Day 30 mm Connection/Day	20.00 40.00 60.00

Notes: Besides these consumption based rates, there is also a water connection fee varying from Rs. 700 to 120,000 depending upon use category, supply line diameter, and plinth area.

[a] These rates apply only to buildings with over 70 percent plinth area in domestic use. For those with 10 to 30 percent plinth area in domestic use, the minimum charge is Rs. 1000 and the rates for the two slabs are: Rs. 5 and Rs. 7 respectively.

[b] The minimum monthly charges in this category are: Rs. 1000 for industries, Rs. 1500 for multi-storey buildings used for commercial use, and Rs. 150 for other non-domestic uses.

Source: Government of Andhra Pradesh (1993).

Although the lower rates for users in non-MCH areas and higher rates for industrial and commercial units are designed to reflect some equity and ability to pay considerations, the actual results in these respects are only of marginal consequences. For one thing, consumers using far lower than 15 cum and paying a fixed fee will be paying more per unit than many others. For another, since the rates are almost the same for consumption above 500 cum irrespective of whether it is individual households, multi-storey buildings, or industrial/commercial units, the current rate system fails to distinguish both the users and uses. As a result, its equity significance is as limited as its efficiency and conservation impact.

How inadequate the rate structure to reflect supply cost can be seen from the fact that while the average cost of water provision has increased from Rs. 0.88 to Rs. 5.58/cum during 1989-95, the rate structure yields an average water charge of only Rs. 3.62. Since it is this uneconomic rate structure including the price perception which it generates among consumers that determines the economic environment for water use decisions at the user-end, it provides very little incentive for the exploration of micro level supply augmentation options including use efficiency and conservation efforts.

SUPPLY AUGMENTATION: ECONOMICS OF ALTERNATIVE OPTIONS

The stage is now set for the identification and evaluation of the economic and institutional aspects of alternative supply augmentation options. Before that, it is necessary to understand the ways in which the water deficit of such a magnitude is managed both at the macro level of water supply system as a whole as well as at the micro level consumers either as individual or as groups. This will enable one to understand how both the relevance and scale of supply augmentation options vary at different levels of the water suppply system.

Macro Level Options

In addition to the supply augmentation options involving the proposed inter-basin water transfers from Krishna and Godavari rivers, the macro level options for managing water deficit at the system level also include supply management strategies inolving the allocation of available supply water thorugh administrateive means. It is a normal practice of most urban water supply agencies especially in developing countries to manage the water deficit by following a combination of supply hour manipulation and differential inter-city water allocation.[8] At present, the average supply hours observed for Hyderabad is only 3 hours/day but it is expected to be 6-7 hours/day after 2001 when supply augmentation occurs from Krishna River. Besides, the actual supply hours is not uniform throughout the city as areas of economic and political importance could manage to get water for more hours than areas with less organized or dispersed pressure groups. As a result, the water deficit is distributed unequally across regions and uses within the city limits.

As can be seen from Table 5, while the water demands of major industries and business units are fully met, that of the MCH and non-MCH areas are met only partially. Between the MCH and non-MCH areas that share among them the full water deficit , the non-MCH area takes most part of the city's water deficit as current net water allocation covers only 28 percent of its net demand. In contrast, the net allocation to MCH area covers over 64 percent of its net demand. Notably, this unequal distribution of water deficit across regions and groups is expected to continue till 2021. Even within both the MCH and non-MCH areas, pockets dominated by groups with greater articulation of their demand get a priority over others in water allocation. Another aspect

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[8] The supply hour manipulation policy is followed with a view to ration the available supply by rotating the supply among different parts of the city. Since reduced supply hours is also accompanied by supply availability at odd hours and low pressure, the total water availability at the user-end becomes still lower (see Nickum and Easter, 1994; Youngh, 1996).

implicit in the pattern of net water allocation is that the residential use category suffers more from water deficit than non-domestic uses.

Table 5. Area and Use-wise Net Demand and Supply Allocation, Hyderabad, 1996-2021.

Particulars	Year				Scenario with Saturated MCH[a]
	1996	2001	2011	2021	
NET WATER DEMAND (mcm)					
(a) MCH	241	287	394	501	550
(b) Outside MCH	104	132	192	263	263
(c) Industrial & Commercial Units	22	25	36	46	49
Total (a)+(b)+(c)	367	444	622	810	862
NET ALLOCATION (mcm)					
(a) MCH	155	254	303	501	550
(b) Outside MCH	29	55	133	263	263
(c) Industrial & Commercial Units	22	25	36	46	49
Total (a)+(b)+(c)	206	334	472	810	862

[a] Relates to the full development of the city with population stabilizing around 10.45 million. These figures are obtained from all the reports of the Hyderabad Water Supply Corporation cited in this paper.

Source: HMWSSB (1995b:83).

Micro Level Options

While the water supply agency manage the water deficit through a mix of supply hours manipulation and an informal and unequal rationing of the total water deficit across regions and use categories, consumers--both within the domestic and non-domestic sectors--deal with water deficit at their end by relying on a variety of water augmentation options depending upon their economic capacity. Since the options available for poor groups are obviously limited, their reliance on the metro water is relatively higher as compared to economically well-to-do users (including non-domestic consumers) as they have more options for tackling water deficit at their end. These options range from investment in in-house storage system to the installation of their own wells[9] Besides, rich households and non-domestic users like hotels and cinema halls also rely regularly on purchased water from private tankers.

Although there are many micro level options, only very few are being adopted that too rather infrequently. Even this is confined to a small segment of consumers essentially to supplement rather than substitute metro water. In addition to these supply augmentation options already being relied upon by consumers, there are also other potentially usable and technically feasible options at the micro level options like privately-organized water transfers through water purchases from farmers as well as water supply through groundwater sources jointly owned wells by neighborhood groups or other inter-household water sharing arrangements including local level inter-household or inter-sectoral water markets.

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[9] Another household level option particularly for tackling the low pressure problem is the use of suction pumps to draw water straight from metro pipelines. But, this practice is prohibited in Hyderabad as in many others cities in India. Chennai (Madras) that disallows the installation of suction pumps, however, allows the use of hand pumps.

The continuation of the problem of water loss and wastage despite the varied responses to water deficit at different levels means that the responses are both insufficient and ineffective to address the basic problem of water use inefficiency. In this respect, the issue of how to encourage the widespread adoption of options currently confined to a small segment of consumers and the active exploitation of many other feasible micro level supply augmentation options is much more important than the macro level options like supply management and inter-basin water transfers. Since most micro level options are private in nature, supply augmentation occurs at the user-end with an in-built individual incentive for water use efficiency and conservation.

While the strategic significance of economically activating various micro level supply augmentation options is obvious, there is a need for an economic evaluation of the options involving supply augmentation through large scale inter-basin water transfer vis-à-vis other local level supply augmentation possibilities. In this respect, at least, there are 11 different options of varying economic costs and feasibility status (see Table 6). While the relative unit costs of alternative options reported in Table 6 are actually based on empirical estimates made by various agencies, a few words on the assumptions and estimation basis behind these estimates should precede the evaluation of their economic and institutional implications .

Table 6. Estimated Unit Cost of Alternative Supply Augmentation Options, Hyderabad, 1996

SUPPLY AUGMENTATION OPTIONS	COST (Rs/cum)
1 Groundwater from Own Wells (Flats)	0.55
2 Municipal Water Connection (Flats)	1.23 to 1.53
3 Groundwater Diversion from Irrigation	2.95
4 Strengthening and Rehabilitation Scheme	3.06
5 Surface Water Diversion from Irrigation	3.50
6 Water Transfers from Godavari and Krishna Rivers	2.29 to 4.40
7 Average Municipal Water Charge	3.62 to 3.94
8 Actual Supply Cost of Municipal Water	5.58
9 Groundwater from Own Wells (Individual House)	6.61
10 Water Supply through Metro Tankers	20.00
11 Water Supply through Private Tankers	31.25 to 62.50

Sources: HMWSSB for options 4, 7, 8, and 10; Centre for Economic and Social Studies, Hyderabad for options 1, 2, 3, 5, 9, and 11; and National Water Development Agency, New Delhi for option 6.

The unit costs of water from own wells and municipal connection for flats are obtained by assuming a set of 13 flats and a water consumption of 42 cum/household/month (which is actually the average consumption level observed in water consumption surveys). The annual cost of ground water from own wells is based on a well and pumpset installation cost of Rs. 20,000 (with 15 years of pump life) and an annual maintenance, repair, and electricity cost of Rs. 2000. The annual cost of municipal connection for flats is obtained by adding the annual water charge of Rs. 7800 (Rs. 650/month) with an one-time payment for municipal connection of Rs. 30,000 being annualised for 20 years. Depending upon whether the lump sum connection payment is included or not, the unit cost of water will vary from Rs. 1.23 to 1.53/cum).

While the unit cost of groundwater diverted from irrigation is based on the irrigation cost (i.e., well, pumpset, electricity charges, etc.) of Rs. 19,760/ha and a water duty of 0.67 hectare--meter (ham), the same for surface water is based on Rs. 35,000/ha as the cost of creating one ha of irrigation potential and a water duty of 1 ham (in view of higher water use and water loss observed in surface irrigation projects). Notably, if the canal water charge of Rs. 100/ha/year is taken as the cost instead of the actual cost of irrigation provision, the unit cost of the option involving the diversion of surface water from irrigation will be just Rs. 0.01/cum. Even when the water productivity[10] of Rs. 4404/Ha is taken as the opportunity cost of surface irrigation water, the unit cost of water will still be only Rs. 0.44/cum.[11]

The unit cost of inter-basin water transfer estimated by the National Water Development Agency relates to the linking of Godavari and Krishna Rivers. It varies from Rs. 2.29 to Rs. 4.40/cum depending upon the location of the proposed link canal. Obviously, these costs include neither the transmission cost nor the cost of water treatment and distribution. While the average municipal water charge paid by users is based on actual household consumption surveys, the actual supply cost is obtained by using the total cost and total water supply observed during 1994-95 (HMWSSB, 1995b). Since the total supply costs are reckoned only partially by the water supply agency, the actual unit cost for the metro water will be substantially higher than the one reported in Table 6.

The unit cost of water from strengthening and rehabilitation of existing and proposed works has been obtained first by dividing the total cost of the scheme (Rs. 7295 million) by the amount of water storage that will benefit from the scheme (238 mcm) and then by annualising the result over a period of 10 years. While the unit cost of water supply through tankers by private parties is based on a typical tanker capacity of 8 cum and a per/tanker cost of Rs. 250 during ordinary period and Rs. 500 during summer months, the same for metro water is based on a tanker capacity of 5 cum and per/tanker cost of Rs. 100.

Supply Augmentation: Feasibility and Cost Advantage

Before the evaluation of these options as feasible avenues for supply augmentation, it is necessary to recognize few factors that hamper their comparability.

First, since the individual supply augmentation capabilities are limited, they can only supplement rather than substitute metro water altogether. However, if all options are relied on wherever feasible, their collective supply augmentation capabilities could considerably relieve the pressure on and improve the overall efficiency of the metro water supply system. In this sense, the options listed in Table 6 are complimentary at the system level, though some of them are substitutes at the micro level of individual users.

Second, since the set of options differ vastly in terms of their legal and institutional requirements, their relative cost advantages purely on a monetary basis are obviously inadequate to establish their relative feasibility status. For instance, water transfers--undertaken either on public account or through private initiatives--involve legal questions related to water rights as well as institutional issues related to the development of suitable mechanisms for establishing and monitoring inter-sectoral (also, inter-regional) allocations and resolving water sharing conflicts. In the case of water transfers from irrigation undertaken by private parties, in addition to these macro

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[10] It is obtained as the difference between the average yield levels of irrigated and rainfed lands.

[11] While these ridiculously low unit cost of water in term of both irrigation water charges and water productivity is often used to justify water transfers from irrigation to urban areas, the relevant unit cost to be reckonrd for such transfers need to be based on the cost of creating an irrigation potential. This is especially so when these transfers are undertaken under public agencies.

level issues, there are also others like the legal restriction on the movement of water beyond the canal command and the scope for legalized opposition for groundwater sales to urban areas (see Saleth, 1996). More importantly, there is also the need for an organized network for regularly collecting water from farmers and physically transporting and distributing to dispersed urban consumers.[12]

And, finally, since the unit costs of all options involving water transfers pertain to cost at supply source, they cannot be directly comparable to the unit costs of other options that report cost at the user-end. To enhance their comparability, the unit costs of the former set of options have to include some imputations for transmission, treatment, and distribution costs. Since in most cases this imputation cannot be estimated directly, one can utilize the procedure suggested by Young, et al. (1972) and used by Booker and Young (1996) and Gibbons (1986) in which the imputation is estimated as the net willingness to pay (NWTP) or consumer surplus (i.e., the marginal willingness to pay minus the applicable unit price) obtained from a given demand function.[13]

These legal, institutional, and other feasibility issues including the political economy considerations, therefore, remain as caveats to the ensuing analysis of the relative cost advantages of the identified set of alternative supply augmentation options. The unit cost of various options ranges from Rs. 0.55 to 62.50/cum. This range, in fact, defines the feasible economic range not only for various forms of water transfers (i.e., inter-household within urban areas, inter-sectoral between irrigation and urban uses, and inter-basin or inter-regional between river basins and states) but also for fixing urban water charges at economic levels. Since both the actual water charge paid by consumers (Rs. 3.62/cum under average pricing and Rs. 3.94/cum under marginal pricing) and the actual supply cost of metro water (Rs. 5.58/cum) are substantially higher than the cost of water diversion from irrigation (Rs. 2.95 to 3.50/cum), there can be a mutually beneficial inter-sectoral water exchange to be carried out either by private parties or by the metro water undertaking.

Similarly, in view of the relative cost considerations, both the consumers with either partial or complete reliance on water from private tankers as well as those relying exclusively on metro water can supplement their water requirements with water from other consumers with own ground water supply. The scope for such ground water exchange (as also for joint private initiatives) within urban areas is enhanced by the fact that given the fixed installation costs of well and pumpset on the one hand and lower electricity charges on the other hand, both the average and marginal costs declines with increased water extraction. The vast unit cost differential between groundwater supply used by a group of households and the same by an individual household (options 1 and 9 in Table 6) indicates, in fact, the economic scope for joint supply arrangements as well as inter-household water sharing within a given locality.

While the actual cost of municipal water to individual households is Rs. 3.62 (under average pricing) to 3.94/cum (under marginal pricing), the same for a household in flats system comes to only Rs. 1.53/cum. This means that under the existing water rate structure, consumers

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[12] Such a system of organized private water collection and distribution network has been observed in many cities and towns in the neighboring state of Tamil Nadu (e.g., Chennai (Madras), Pudukkottai, and Thirupathur) where a number of private tankers collect water from farmers in far away villages and sell to urban--both domestic and non-domestic--consumers on a regular basis.

[13] While this procedure will be detailed later when it is applied for calculating the willingness to pay for water, here it is sufficient to say that the NWTP for our sample ranges from Rs. 0.01 to 2.20/cum (see Table 11). It is reasonable to assume an average value of Rs. 1.00/cum as the value that the consumers are willing to place on those costs involved in converting raw water at supply source into treated water at user-end.

living in flats benefit from scale economies on the cost side whereas the metro water supply undertaking suffers because there is a diseconomy of scale on the demand side as the water consumption by flats is enhanced by the lower prices at the consumers' end. This fact plus the difference between the unit cost of water for the consumers and the metro water supply agency underlines the centrality of the option involving the revision of both the level and structure of water charges.

Economic pricing of water is necessary not only for improving the financial viability and water use efficiency of the system but also for providing incentive for private initiatives especially in the form of inter-household and inter-sectoral water exchanges and joint ownership and management of ground water wells and other water supply sources by user groups. Moreover, the economic viability of supply augmentation schemes involving inter-basin water transfers from Krishna and Godavari is also strongly predicated on the adoption of suitable price structure.

In addition to the institutional implications of the option involving water sqpply tariff revision, there are also obvious financial and water use efficiency implications. In other words, the pricing option has an instrumental role in promoting other less costly options (e.g., inter-household and inter-sectoral water exchanges, efficiency improvement, etc.) which can either delay or reduce the size of investment-wise costly options like Krishna and Godavari water transfers. Besides, given the indispensability of costly options for meeting the future growth in water demand, the pricing option also has a tremendous potential to release and generate funds for future supply augmentation projects partly by activating less costly supply supplements and partly by assuring a higher and more progressive water charge.

PRICING STRUCTURE, WATER DEMAND, AND SUPPLY AUGMENTATION

Unfortunately, the existing structure of water supply tariff in Hyderabad seems to be less suited for playing the strategic role expected under the pricing option. While it is true that Hyderabad being supported under the World Bank-aided schemes has a higher levels of water rates (which are also being revised more often), as compared to other cities like Delhi with obvious improvement in the overall financial health, the rate structure, with a still substantial regressive character, does not provide economic incentives strong enough for economically activating various local level supply augmentation options including efficient water use.

In order to demonstrate the undesirable incentive effects of the existing pricing structure and to delineate the character of a new and more efficient pricing structure, the empirically estimated water demand functions desegregated by consumption brackets and housing types can be utilised. At this stage, an issue-based analytical review of the existing literature will be useful to provide both context and justification for the kind of estimation exercise to be performed in the subsequent section.

Existing Literature: An Analytical Review

In the scheme of this paper, since the estimation of the residential water demand function is not considered as an end in itself but as a means for demonstrating the centrality of pricing option within the spectrum of supply augmentation options, a detailed review of the extensive literature on water demand function is beyond the scope of this paper.[14] Nevertheless, a brief literature review focused mainly on major analytical and methodological issues is still necessary for the purpose of

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[14] For a comprehensive review of urban water demand studies, see Boland, et al. (1984), Gibbons (1986), Herrington (1987), and Young (1996).

this paper. Although the empirical estimation of residential water demand functions dates back to 1926, more systematic and sophisticated attempts in terms of demand specification and methodology have started only since the 1960s. A careful review of the recent attempts reveals five main points which are of direct concern to our ensuing estimation exercise.

First, most of the existing studies estimate residential water demand functions in the context of mature urban water supply systems prevalent in advanced countries especially the US rather than in the context of poorly performing urban water supply systems characteristic of most developing countries. As a result, the estimated demand functions, irrespective of the estimation context and data, yielded well behaved demand function with the expected significant negative sign for the price variable.[15]

Second, even though the estimation of residential water demand functions within a micro setting using household level data is the most preferred approach (see Schefter and David, 1985; Young, 1996), attempts at the micro level are rather very few as most studies estimate water demand in a macro context of regions/communities/cities or time points.[16]

Third, while there are studies that disaggregate demand functions by regions/communities (e.g., Howe and Linaweaver, 1967; Wong, 1972; Foster and Beattie, 1979), by seasons (e.g., Howe and Linaweaver, 1967; Young, 1973; Danielson, 1979; Griffin and Chang, 1991) and by peak and off-peak conditions (Lyman, 1992), with very few exceptions (e.g. William and Suh, 1986; Schneider and Whitlach, 1991), there is hardly any study that disaggregate water demand functions by well defined user groups.

Fourth, since urban water is priced mostly under a block rate system--either in its increasing or decreasing forms--with a flat fee for the lowest consumption slab, the specification of appropriate price variable is crucial for the correct estimation of water demand functions. Although earlier studies used either average price (e.g., Wong, 1972; and Foster Beattie, 1980) or marginal price (e.g., Howe and Linaweaver, 1967) as the only price variable in the water demand function, most of the recent studies used marginal price along with a difference variable capturing the difference between the actual water bill minus the bill that would have resulted if all units were priced at the marginal price (e.g., Billings and Agthe, 1980; Nieswiadomy and Molina, 1989). While Gibbs (1978) and Griffin and Martin (1981), among others, argued the marginal price formulation to be a better representation of consumer behavior, Foster and Beattie (1981) and Shin (1985) have empirically demonstrated that average price reflects well consumer's price perception under the block rate system.[17]

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[15] However, there are also few studies that report positive price coefficient (e.g., Gottlieb, 1967; Nieswiadomy and Molina, 1989; Nieswiadomy, 1992).

[16] For instance, 79 percent of the 124 elasticity estimates obtained from papers published during 1967-93 are related to macro context and aggregate data (see Espey, et al., 1996). To our knowledge, studies estimating micro level water demand are: Danielson (1979), Billings and Agthe (1980), Hanke and de Mare (1982), Deller, et al. (1986), Chicoine, et al. (1986), Jones and Morris (1984), Agthe and Billings (1987), Nieswiadomy and Molina (1989), Schneider and Whitlach (1991), Hewitt and Hanemann (1996). Even among them, while Billings and Agthe (1980) and Agthe and Billing (1987) use only average figures rather than the actually observed household water consumption, Deller, et al. (1986), Chicoine, et al. (1986), though use household data, estimate water demand in a rural rather than in an urban context.

[17] Although Foster and Beattie (1981) found their demand estimate under the average price is almost identical to that under the marginal price formulation including the difference variable, we will argue below and demonstrate later with our demand estimates that the latter price formulation has important methodologi-

And, finally, while most of the demand estimations are based on the Ordinary Least Squares (OLS) technique, studies relying on advanced estimation procedures based on instrumental variables (IV) approach (e.g., Deller, et al., 1986; Nieswiadomy and Molina, 1989), 2-Stage Least Squares (2-SLS) technique (e.g., Nieswiadomy and Molina, 1989; Mckean, et al., 1996), and 3-Stage Least squares (3-SLS) technique (e.g., Agthe, et al., 1986; Chicoine, et al., 1986) are also growing in recent years due to the belief that OLS estimates under block rate system has an inherent problem of simultaneity between quantity and price.

Some of the points noted above have already touched two of the most serious and still unresolved controversies persisting in the current literature on water demand in particular and block rate pricing in general. While the fourth point is related to the economic and behavioral issue of whether it is the average price or the marginal price that accurately reflects users' price perception, the last point is concerned with the econometric issue of simultaneity bias.[18] Interestingly, both these issues are interconnected as they have their origin in the block pricing system with a fixed fee component. Under the block pricing system, since price becomes endogenous varying with consumption, there is a vast scope for simultaneity. This problem gets, of course, magnified when the average price (i.e., total water bill divided by total water consumed) that makes price as an explicit function of quantity is specified as the only price variable in the demand function.[19]

In order to avoid the simultaneity problem inherent in block pricing, Taylor (1975) has suggested the use of both the average and marginal prices as they could capture more accurately the effects of intra-marginal rates and fixed fees on demand. Later, Nordin (1976) has theoretically modified Taylor's proposition with the use of marginal price and the difference variable that captures the effects of price-induced income changes on demand.[20] Notice that with a given quantity or budget share of water bill, the difference variable captures the full extent that a user can adjust quantity to price and *vice versa.* In this sense, the marginal price formulation involving the difference variable seems to solve the econometric problem of simultaneity via the incorporation an economic variable capturing the price-quantity adjustment potential.

The relevancy of this solution gets, however, limited when either the budget share of water bill varies significantly or the difference variable is itself subject to simultaneity problems, or there is scope for substituting the metro water with water from alternative sources. Under these conditions, since the difference variable approach of solving the simultaneity problem is inadequate, more direct econometric approaches involving the use of improved estimation techniques like IV, 2-SLS, and 3-SLS are needed for simultaneity correction.

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cal advantages. In particular, contrary to the perception in the literature, the marginal price formulation does not contradict but presupposes the average price behavior. Thus, the average vs. marginal price debate is not so much a controversy on price specification *per se* as that on the relative relevance of the positive vs. normative approach to consumer behavior under block rate pricing.

[18] The price specification controversy has another related dimension as Griffin and Martin (1981) argue that when consumers face a rate schedule, the whole price schedule rather than any single price--whether the average or marginal price--has to be used in demand estimation. In fact, Nieswiadomy and Molina (1989) use such a price formulation in their IV and 2-SLS-based empirical exercise.

[19] This can also happen even when marginal price alone is the price variable. For more detail, see Billings and Agthe (1980).

[20] Even though the difference variable captures income effects, it is considered essentially as a price rather than an income variable (see Shin, 1985).

From a practical viewpoint, however, the real questions in this respect are: is there a strong enough economic basis for simultaneity? If there is, how serious is its effects on actual consumption decision and hence, on the demand estimates? Addressing these questions, Foster and Beattie (1981) noted that the basic condition for simultaneity, i.e., users' perfect knowledge of the rate structure, remains mostly unmet in practice. They argued further that even with perfect knowledge, the users will not have the incentive to use such knowledge for taking consumption decisions as long as water bill forms only a tiny fraction of total household expenditure or income.[21]

The extent of price-induced adjustments in municipal water demand that occurs in practice depends not only on the magnitude of the price-induced income effects but also on the substitution effects capturing the extent users can rely on water sources alternative to metro supply. With lower water rates and little difference between rates for subsequent consumption slabs, the magnitude of these income and substitution effects are likely to be lower than that necessary for the existence of the simultaneity problem. This is especially so when most users rely almost exclusively on pre-treated metro water for certain essential uses like drinking and cooking either on cost/quality considerations. In such situations, there is little economic basis for the econometric issue of simultaneity and even if it were there, it will not be serious enough to alter consumption decisions (Foster and Beattie, 1981:627).

Although there are studies (e.g., Nieswiadomy and Molina, 1989) which provide evidence for the simultaneity problem, there are also evidences to the contrary.[22] It seems that the empirical relevance and validity of the simultaneity problem are more contextual as they depend on the estimation context and data set. Simultaneity is likely to be a serious problem in the context of both aggregate data where there is scope for spatial and temporal variations in the rate structure as well as micro data when the sample is dominated by users in the lowest consumption slab with a fixed fee. Obviously, studies using data with one or more of these characteristics (e.g., Billings and Agthe, 1980; Nieswiadomy and Molina, 1989) may require an explicit econometric correction for simultaneity through the use of IV, 2-SLS, or 3-SLS estimation techniques. But, one cannot ignore the fact that such correction, though needed for eliminating the simultaneity problem, could itself lead to other equally serious econometric problems.[23]

Although the relative seriousness of the simultaneity bias and the bias inherent in its econometric correction is an empirical issue, we hypothesize that the latter is likely to be serious in all contexts where the economic basis for simultaneity is either absent or minimal. Even when the potential for simultaneity is significant, the use of the difference variable will be sufficient particularly in contexts where the data allows the estimation of disaggregated demand functions for

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[21] This argument has strong empirical support. For instance, while Shin (1985), who calls the difference variable as the 'rate structure premium' (i.e., the value of rate structure information), has found its value to be only 0.70 percent of the mean income for his sample, Nieswiadomy and Molina (1989) have observed in their sample that the mean value of the difference variable is just 0.01 percent of the mean household income.

[22] For instance, Jones and Morris (1984) report that their OLS estimates are not fundamentally different from their IV estimates. The demand estimates performed for the present paper did also show that the OLS and 2-SLS estimates are almost identical.

[23] Since the inclusion of the difference variable in itself could minimize the effects of simultaneity, attempting an explicit econometric correction on top of it could lead to an over correction problem. Besides, the multicollinearity problem can also be serious when the values of the price and difference variables predicted by using other variables in the first stage are included along with the same set of variables in the second stage.

different user groups defined preferably by consumption brackets and water demand potential. In this case, the simple OLS estimation procedure can yield more reliable water demand estimates.

Turning now to the average vs. marginal price debate, the most important question in this respect, at least, from the perspective of this paper, is not the normative issue of whether water consumption decisions are actually based on average or marginal price but the positive or practical issue of users' consumption response when they are made (through suitable policy changes) to perceive marginal price instead of the average price as the price variable facing them. The approach involving the use of the marginal price with the difference variable, though used often to rationalize marginal price-taking behavior, in fact, captures implicitly the effects of price switch (i.e., from average to marginal price) on consumption.

Notice that when the magnitude of the difference variable capturing the difference between the actual bill and that possible with marginal pricing is negative and significant, it is presumed that users are perceiving a price other than the marginal price which, given the block rate system and the information problems noted by Foster and Beattie (1981) and Shin (1985), could essentially be the average price.[24] That is, the marginal price with the difference variable approach accepts the average price behavior but investigates the consumption behavior of users when they are made to perceive the marginal price instead of the average price. Since the marginal price approach does not contradict the average price behavior, it cannot be used as an argument against the average price behavior. It is useful, at this stage, to recount briefly the main messages that the preceding analytical and issue-based literature review has for the specific purpose of this paper.

First, the average vs. marginal price debate has actually sidelined few issues which are important from the viewpoint of urban water pricing. Since the attention is unduly concentrated on price perception and hence, on the level of price, the much more important effect that price structure has on consumption could not be addressed adequately. Although a switch from average to marginal price does influence consumption, its effects, however, get considerably diluted when the price structure is regressive with very low incremental slab rates. In this case, the price switch per se, though necessary, may not be sufficient without a substantial change in the rate structure itself.

Second, given the positivist nature of the average pricing behavior and the normative nature of the marginal pricing behavior, the estimation and comparison of demand functions under both prices are highly useful in demonstrating their relative incentive properties particularly from the viewpoint of encouraging the adoption of local level supply augmentation options and justifying the economic need for large scale supply augmentation projects.

Third, for the purpose of identifying the appropriate level of water rates, suitably estimated demand functions could provide valuable information. For instance, given the demand curve and its price elasticity, consumers' willingness to pay for water can be calculated and used for determining not only the economic water rates but also the consumers' willingness to pay for raw water (see Young, et al., 1972; Gibbons, 1986; Booker and Young, 1996).

Fourth, a point somewhat related to the one discussed above is that the magnitude and direction of consumption response as induced by the price switch need to be considered more

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[24] Note that when the average price is used, the difference variable will be insignificant as the actual bill will be closer, if not identical, to the one that results with average price. Besides, under an increasing block pricing system, the price coefficient can also be positive especially when micro level panel data is used. This does not necessarily mean that the function being estimated is the supply instead of the demand function as argued incorrectly by Griffin, et al. (1981).

explicitly so as to evaluate the role of prices in inducing water use efficiency and conservation and in activating alternative supply augmentation options at the micro level.

And, finally, since the price switch captures the effects of pricing level (as measured by the gap between the average and marginal prices) on consumption, the response function could be useful in designing suitable pricing structure as it helps not only in identifying appropriate and group-specific price hike but also in evaluating the willingness and ability to accept the price hike under alternative prices.[25] The latter is useful in identifying the extent various alternative supply augmentation options are within the economic reach of both users and urban water supply agencies.

Methodology

With our preceding review of existing literature serving as a solid background for our analysis, we are now ready to specify our water demand model and the estimation procedures. In order to specify the empirical models of water demand, we define the following variables:

Q = Average Observed monthly consumption of water in cum,

q_i = Average monthly consumption within tier i in cum,

q_l = Monthly consumption in the lowest consumption slab (i.e., up to 15 cum),

F = Fixed payment for consumption up to 15 cum in Rs,

p_i = The tariff rate for consumption tier i in Rs/cum,

P^m = $[(F/(q_l - 1) - (F/q_l)]$ for quantity up to 15 cum but p_i for quantity over 15 cum,

P^a = F/q_l for quantity up to 15 cum but $[F + \Sigma p_i q_i]/Q$ for quantity over 15 cum,

D^m = Actual monthly bill at existing rates minus that under P^m,

D^a = Actual monthly bill at existing rates minus that under P^a,

ΔQ = The difference between consumption at P^m and that at P^a,

ΔP = The difference between P^m and P^a,

N = Number of members in the household, and

H = Housing category.

Before specifying the water demand models, it is useful to note few points to clarify some of the less obvious variables defined above. As can be seen from Table 3, there are four consumption tiers--first one with a fixed payment F and the rest with tier-specific unit rates. P^m and P^a are respectively the marginal and average prices facing the consumers. Notice that P^m is not zero for the lowest consumption slab with the fixed fee F. It is derived as the absolute difference between the average price of the last unit and that of the penultimate unit.

While D^m is not zero (positive when $P^a > P^m$ but negative when $P^a < P^m$), D^a will be zero as long as consumers use P^a as the price variable in making their consumption decisions. Although our data set does not have a straightforward income variable, the variable H denoting the housing category can be taken as a proxy for household wealth or economic status. Since H takes the value

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[25] Notice that when the response function is estimated with a log-log functional form, the coefficient of the price change variable measures the elasticity of consumption change. This coefficient can be used to indicate the level of price change needed to effect a given level of consumption change.

either 1, 2, 3, or 4 depending upon whether the house in question is a bungalow with garden, bungalow without garden, traditional house, or house in the slum areas, it has an inverse relationship with the economic/asset status of the household.

Given the definition of variables, the general expression of the residential water demand function to be estimated can be specified as:

$$Q = f(\underline{P},\underline{D},N,H) \tag*{[1]}$$

Where $\underline{P} = P^a$ or P^m, $\underline{D} = D^a$ or D^m, and N and H are as defined above. Since D^a is zero as the actual water bill of the consumers is identical to the one that will result from that under P^a, the demand function under an average pricing behavior boils down to:

$$Q = f(P^a,N,H) \tag*{[2]}$$

But, since D^m is not zero, the demand function to be estimated under the marginal pricing behavior will be as follows:

$$Q = f(P^m, D^m, N,H) \tag*{[3]}$$

Notice that the expressions for the demand functions [2] and [3] imply that there are differences not only in the behavioral postulates but also in the information level assumed to be available to consumers. When average pricing behavior occurs, consumers' knowledge on the rate structure is either absent or of less value for making consumption decision (Foster and Beattie, 1981; Shin, 1985). As has been argued already, even though there is some mathematical basis for simultaneity, its practical effects on consumption will be inconsequential. Therefore, equation [2] can be estimated using simple OLS technique.

On the other hand, under the marginal pricing behavior, consumers are assumed to have full knowledge on the rate structure and its implications. In this case, there is scope for simultaneous adjustment between price and quantity. As established already, with a given rate structure, consumption quantity, and budget share of the water bill, the inclusion of the difference variable is itself adequate to capture the adjustment potential and there is no need for any explicit correction for simultaneity through econometric means. Therefore, equation [3] can also be estimated using the OLS technique. By estimating and comparing the two demand function with different behavioral and information content, one can demonstrate the favorable effects of the price switch.

While equation [3] implicitly considers the consumption effects of the price switch, it is useful to consider more explicitly the consumption response by estimating the following function:

$$\Delta Q = f(\Delta P,N,H) \tag*{[4]}$$

Notice that unlike the demand function in equation [3] that assumes either a given quantity or a given water bill, equation [4] defining the response function, however, allows changes in both the consumption quantity and water bill. Besides, it can also permit substitution of metro water with water from non-metro sources. Obviously, the latter can provide more realistic information on consumption behavior when the actual consumption is below the full requirement and the tiny budget share of water bill allows increased expenditure on water consumption. More importantly, the response function can also provide key information for determining the level of water rate hike needed to realize either a given reduction in consumption or a given increment in revenue (i.e., when consumption is non-responsive to price hike).

Nevertheless, the response function is not a substitute for the demand function as it is the price elasticity derived from the latter that gives a means for estimating consumers' willingness to pay (WTP). Given the WTP, the willingness and ability to accept the price hike or adjust their metro water consumption can be determined from the net willingness to pay (NWTP) obtained by subtracting the prevalent water rate from the WTP.

Given the demand function and its price elasticity, the NWTP can be calculated following the procedure suggested by Young, et al. (1972). This procedure that requires the price elasticity to be constant but non-unitary within a relevant range involves three steps. First, the area under the demand curve for a given quantity change is calculated using the following formula:

$$V = [PQ_1^x/(1-x)]\,[(Q_1/Q_1^x) - (Q_2/Q_2^x)] \qquad [5]$$

where $x = (1/|e|)$, e = price elasticity, P = initial price, Q_1 = initial quantity, and Q_2 = changed quantity. Then, the area V obtained from equation [5] is divided by (Q_1-Q_2) and the water price P is subtracted from the resultant value. What we get at the end of the procedure is the consumer surplus for the marginal increment in quantity that approximates users' NWTP.[26] As can be seen from equation [5], the value of NWTP is affected by the absolute value of price elasticity, the extent of quantity change, and the level of initial price. While price elasticity has an inverse effect on NWTP, the quantity change considered for calculating NWTP has a direct effect on the same. Notably, the relationship between the initial price and NWTP is such that when the price is doubled, the value of NWTP will also get doubled.

The NWTP has important roles in the particular context of this paper. First, it helps in establishing the value that the consumers place on raw water under the existing water rate structure. In this case, the NWTP can also be of use in approximating the transmission, treatment and distribution costs that separate raw water at source from tap water at the user-end. Second, it is also useful in determining how many alternative supply augmentation options which are listed in Table 6 are actually within the economic reach of users at current rate structure. And, finally, since it helps in determining the feasible range for price hike, it can provide useful information for designing efficient water rate structure that can be instrumental in activating supply augmentation options which otherwise remain outside the economic sphere of users under the existing water rate structure.

Since the water tariff structure has a differential impact on different groups of residential water users, it is found necessary to perform the estimation of equations [2], [3], [4], and [5] in the following contexts: (a) all households taken together, (b) households differentiated by two consumption brackets (i.e., consumption less than 15 cum/month and over 15 cum/month), and (c) households distinguished by four housing categories (i.e., bungalows with garden, bungalows without garden, traditional houses, and houses in slum areas). A disaggregated estimation exercise performed in these estimation contexts is helpful in understanding both the overall and group-specific price responsiveness and consumption behavior as well as the economic potential for accepting and adopting water supply augmentation potential. Finally, for the convenience of interpreting the price coefficient as price elasticity, both the demand and consumption response functions are estimated using the log-log functional form.

PRICING BEHAVIOR AND WATER DEMAND: REGRESSION RESULTS

The data for the empirical estimation of the postulated water demand models under various pricing behavior comes from a household survey commissioned by the HMWSSB during 1991-92. Although the survey covers a sample of 862 households located in the MCH area, for the purpose of

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[26] Note that the parameter x being the inverse of elasticity reflects the price flexibility or responsiveness of the demand function and measures the effects of a proportional change in consumption on the value of water to the users (see Young, 1996:76).

estimating demand function, four cases representing flats were excluded. While the survey provides information on household-specific water consumption based on actual meter reading, the household size, and the housing category, it does not provide straightaway the crucial information on the actual water payment paid by each household. However, based on metered water consumption and the water rate structure in Table 4, the applicable water bill under both the average and marginal pricing schemes were derived..

Table 7 gives the descriptive statistics for all the major variables used in various estimation contexts. Few points in Table 7 need noting as they will be of use while interpreting demand estimation results. Of the total sample, 86 percent of the households have water consumption exceeding 15 cum/month.[27] Since 74 percent of the 124 households located in the lowest consumption slab fall either in housing category 3 (32 percent) or 4 (42 percent), there is a general linkage between housing type and consumption bracket. While mean water consumption varies inversely with housing category, mean variation moves directly with the same. This means that economically better placed households consume more water than others even though the latter usually have larger family size.

Table 7. Descriptive Statistics for Model Variables in Various Estimation Contexts.

Estimation Context	Variables[a]					Sample Size
	Q	P^m	P^a	D^m	N	
(A) All Cases	39.391 (32.927)	3.945 (1.682)	3.616 (1.209)	-30.411 (33.764)	8.043 (4.178)	858
(B) Consumption Bracket						
Q≤15 cum	10.291 (3.188)	0.928 (2.602)	4.578 (2.640)	34.494 (4.614)	6.774 (3.691)	124
Q>15 cum	44.308 (33.154)	4.455 (0.891)	3.455 (0.596)	-41.376 (22.277)	8.257 (4.219)	734
(C) Housing Category						
H= 1	60.604 (40.221)	4.682 (1.014)	3.912 (0.829)	-47.686 (22.451)	8.292 (4.084)	57
H=2	45.206 (35.748)	4.288 (1.374)	3.600 (0.655)	-39.084 (29.231)	7.230 (3.515)	344
H=3	36.369 (31.783)	3.873 (1.842)	3.638 (1.642)	-26.886 (33.850)	8.858 (5.006)	261
H=4	27.040 (18.754)	3.225 (1.845)	3.526 (1.356)	-14.847 (36.798)	8.311 (3.824)	196

[a] Figures in each cell are respectively the mean and standard deviation.

Source: Authors' calculations.

While $P^a > P^m$ for household with consumption less than 15 cum as well as those located in the slum area, for others, it is: $P^a < P^m$. As a result, the difference variable D^m is positive in the former case but negative in the latter case. While a positive value for D^m implies a subsidy, a negative value implies a kind tar on water consumption. As one could expect that the absolute

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[27] This in contrast to studies like Nieswiadomy and Molina (1989) where the household level sample is dominated by consumers in the lowest consumption slab requiring only a fixed fee. Such a sample composition has fundamental implications for demand estimates.

magnitude of D^m varies directly with both the consumption level and housing category. Finally, unlike P^a that favours larger consumers, P^m that varies directly with consumption level and economic status of the households is preferable both from equity and efficiency perspectives in addition to its revenue augmentation characteristics.

Water Demand Under Average Pricing Behavior

Under the existing price structure characterized by increasing intervals between successive consumption slabs and slab-specific constant water rates, the water consumption decision is not affected by the marginal price but only by the average price. The scope for the average pricing behavior is enhanced further by the information problems noted by Foster and Beattie (1981) and Shin (1985). Under the average pricing behavior, the consumer surplus will be maximised only when consumption is extended up to the quantity corresponding to the average price that declines with each increase in consumption.[28] This clearly means that the water demand function will have a positive rather than the usual negative slope. Of course, the magnitude of the slope varies with contexts as defined by consumption brackets and housing types. By comparing the demand functions across estimation contexts, it is possible to show not only the perverse effects of existing pricing structure but also how these effects vary by situation.

Table 8 depicts the context-specific coefficients of the demand functions estimated under average pricing behavior and log-log functional form. Although the R^2 is low in most cases (which is normal in cross-section regression), the relative magnitude, direction, and statistical significance of the coefficients do allow us to evaluate the nature and pattern of water demand across consumption and housing categories. In the context of all households, all the three variables are statistically significant and have the expected sign except the price variable with a positive rather than the usual negative coefficient. The reason for this counter-intuitive behavior of price variable lies in the current pricing structure as explained above. The positive coefficient associated with N implies that water demand is directly affected by household water requirement as determined by the family size.

The negative coefficient of H supports the inverse relationship existing between water demand and housing category. Since category 1 includes bungalows with garden and category 4 covers houses in slum, the inverse relation actually implies the positive effect that economic status of the household has on water demand. As we go by the relative value of the absolute magnitude of the coefficients associated with the three variables, it seems that the demand is influenced more strongly by family size and house type than by price. What this means is that the demand is affected more by water requirement than by price considerations.

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[28] However, in practice, consumers cannot increase consumption indefinitely as the maximum consumption of a household is limited either by its maximum water requirement or by water availability as determined by supply hours and pressure of metro water.

Table 8. Water Demand Estimates under Average Pricing Behavior.

Estimation Context	Variables[a]				R^2	F-value
	Constant	P^a	N	H		
(A) All Cases	2.827* (17.851)	0.213* (2.231)	0.476* (10.317)	-0.657* (-11.018)	0.211	56.87
(B) Consumption Bracket						
Q≤15 cum	3.689* (22.578)	-1.000* (-102.327)	-0.0002 (1.049)	0.0001 (0.134)	0.999	2778.44
Q>15 cum	-0.201* (-4.184)	3.047* (87.650)	0.054* (4.357)	-0.024 (-1.540)	0.929	2387.59
(C) Housing Category						
H= 1	1.457* (2.018)	1.378* (3.003)	0.288 (1.468)	–	0.194	4.25
H=2	0.599* (2.803)	1.751* (10.879)	0.417* (6.605)	–	0.378	68.84
H=3	2.484* (9.667)	-0.124 (-0.794)	0.492* (6.202)	–	0.136	13.43
H=4	2.978* (10.342)	-0.667* (-3.993)	0.459* (4.453)	–	0.151	11.36

[a] Figures in each cell are respectively the coefficient and t-ratio and * denotes significance at 5 percent or better.

Source: Authors' calculations.

The pattern of demand observed for the sample as a whole, however, undergoes significant change as we distinguish the sample in terms of consumption brackets and housing categories. Interestingly, among households with consumption less than 15 cum/month, the coefficient for the price variable becomes negative with a significant unitary elasticity. This result is mainly due to the fact that given the fixed minimum payment for consumption up to 15 cum, the average price declines with increasing consumption within the lowest consumption slab. Although the remaining two variables have signs quite contrary to expectation, they are not significant because households in the lowest consumption slab usually have smaller and more uniform family size and fall mostly in housing categories 3 and 4 evincing lower average water consumption .

In contrast, among households with consumption exceeding 15 cum, not only the coefficient associated with the price variable turns positive but also its magnitude becomes several times higher than that obtained in the context of the overall sample. However, unlike the all-household demand function, the demand estimates for both the consumption bracket show that the elasticity of water consumption with respect to price is more stronger than that with respect to the remaining variables. A comparison of the demand coefficients across housing categories reveals that the price coefficients which is positive and significant for the first two house types with better economic status (and hence, larger houses in terms of area and facilities) turns negative for others, though it is not significant for house type 3. This means that price has a dominant positive effect on water consumption among economically well-to-do households but water requirement has that effect on water demand among poor households.

The implications of the differential structure of water demand across consumption and housing categories for the level and efficiency of urban water consumption can now be noted. The perverse demand functions with an increasing slope especially among larger consumers means that the existing price structure encourages water overuse rather than water conservation. While consumers with larger water consumption are insensitive to water rates, those with smaller consumption and lower economic status, though relatively more sensitive to both price and water need considerations, are guided more by their water requirements. Besides their negative effect on water use efficiency and conservation, the level of current water rates and the method of their determination are neither conducive for augmenting revenue for the water supply agency nor favourable for providing the needed level of incentives for water use efficiency among consumers.

Water Demand Under Marginal Pricing Behavior

The incentive gains from inducing a marginal pricing behavior among users can be demonstrated by estimating equation [3] and comparing its coefficients with those obtained from equation [2] that assume the average pricing behavior. The demand function estimates under the marginal pricing behavior are reported in Table 9. As can be seen, the higher R^2 obtained in all contexts suggests a relatively better explanatory power of the demand model in equation [3] as compared to the one in equation [2].[29]

Table 9. Water Demand Estimates under Marginal Pricing Behavior.

Estimation	Variables[a]					R^2	F-Value
Context	Constant	P^m	D^m	N	H		
(A) All Cases	2.948* (47.668)	-0.580* (-15.228)	-0.379* (-29.451)	0.219* (8.145)	-0.237* (-6.716)	0.743	616.31
(B) Consumption Bracket							
Q≤15 cum	2.267* (199.097)	-0.474* (-543.523)	-0.097* (-28.752)	0.001 (0.809)	-0.001 (-0.346)	0.999	1795.99
Q>15 cum	2.267* (199.097)	-5.343* (2.740)	-1.456* (-3.527)	0.273* (8.878)	-0.244* (-6.027)	0.577	248.86
(C) Housing Category							
H= 1	0.391* (1.343)	-0.495* (-2.617)	-0.399* (-4.244)	0.239 (1.524)	_	0.598	65.44
H=2	1.248* (11.238)	-0.718* (-6.369)	-0.430* (-11.556)	0.294* (6.018)	_	0.634	218.57
H=3	1.492* (11.518)	-0.559* (-9.950)	-0.376* (-20.084)	0.206* (4.818)	_	0.764	191.51
H=4	2.262* (17.085)	-0.547* (-13.155)	-0.354* (-24.330)	0.089* (2.102)	_	0.864	206.68

[a] Figures in each cell are respectively the coefficient and t-ratio.

* denotes significance at 5 percent or better.

Source: Authors' calculations.

Before interpreting the results, it is well to recognize that the marginal price being used in the demand estimates pertains to the existing water tariff and consumption slat structures. Since we consider only the marginal prices corresponding to the existing rate and slab structures, the demand

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[29] Notice that the better R^2 obtained for the demand function under the marginal pricing behavior should not be used as an evidence to repudiate the average pricing behavior as it will amount to the ignorance of the considerable policy changes (including pricing reform and consumer education and extension) needed for inducing marginal pricing behavior among urban water users.

estimates capture only the effects of a change in price level as induced by a change in price perception but not the change in the water rate and consumption slab structures. While an effective pricing policy requires the simultaneous perusal of both a price switch and a structural changes in the water tariff structure, the incentive gains even from a mere price switch could still be substantial as can be seen from Table 9.

Effecting a switch from the average to marginal pricing behavior even within the existing water rate structure leads to a radical change in water consumption behavior. Irrespective of the estimation context, the price coefficient that remained mostly positive under average pricing has now become negative and significant. The coefficients associated with the difference variable are also negative and significant due to the following fact. Since under marginal pricing consumers have to pay also the marginal price even for all intra-marginal units, they have to pay more than what they would have paid under the average pricing system. This extra bill, being a negative quantity, produces an effect similar to that of a tax on water consumption.[30] It is, therefore clear that marginal pricing behavior makes users to be relatively more price sensitive and hence, takes them to a higher plane of efficiency and conservation.

As one would expect, even though the coefficients of both the price and difference variables are significantly negative in all contexts, both of them differ considerably in terms of their relative magnitude across contexts. This means that consumers of different categories vary in terms of their price responsiveness. Since the absolute value of the coefficient is less than one in all contexts except when consumption exceeds 15 cum, the demand is mostly inelastic suggesting that the scope for water conservation under marginal pricing is confined mostly to users in the larger consumption brackets.

Across housing categories, as we exclude category 1 (i.e., bungalows with garden), the elasticity of demand varies inversely with the variable H. This suggests that with marginal pricing, richer households could be induced to reduce their metro water consumption and compensate such a reduction by relying on alternative supply augmentation options. Interestingly, bungalows with garden has a much more inelastic demand even as compared to the houses in slum areas. This unexpected result has its origin in the existing slab and slab-specific rate structures where the marginal price remains the same within a larger range at higher consumption levels (see Table 4). Since consumption can be insensitive even under marginal pricing when the water rate structures is inefficient, from the incentive angle, the nature of the rate structure seems to be more important than the pricing behavior per se.

Considering the effects of the difference variable across the estimation contexts, the magnitude of its effect on consumption is uniformly lower than that of the price variable. As we exclude housing category 1, its effects vary inversely with the economic status of the households but positively with consumption level. Since the difference variable is capturing the scope for substitution possibilities at the household level, its relatively stronger effect among larger users and economically well-to-do households augers well for economically activating many viable household level supply augmentation options. Overall, the elasticity of demand or consumption with respect to

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[30] Notice that the consumption reduction implied here relates only to a reduction in metro water consumption but not a reduction in actual water consumption as the magnitude of the difference variable can be such as to induce the households to substitute the metro water with other cheaper non-metro water sources in some non-essential residential uses. Thus, the difference variable capturing the income effects of the price switch does also have the potential to reflect the scope for substitution possibilities.

both the price and difference variables is in the direction of favoring water use efficiency and conservation particularly among larger consumers.

However, the inelastic nature of demand especially among households with the economic capacity for investing in alternative micro level supply augmentation options reduces the prospects of actually adopting these options. This is especially so when the increased price following the price switch is lower than the unit costs of these alternative options. Besides, when the actual water requirements of these households are such that consumption reduction can be accommodated by cutting down water use in certain non-essential uses or minimizing wastage/losses at the household level, there may be little need for the adoption of direct supply augmentation options even though there is considerable incentive for water use efficiency or conservation. On the other hand, among households with a relatively more elastic demand, even a slight change in price could induce considerable reduction in consumption. As long as their consumption is already at or close to their actual water requirement, price switch-induced consumption reduction has to be compensated by direct water augmentation through non-metro means rather than by way of marginal improvements through use efficiency or wastage reduction.

What this means is that the actual scope for the adoption of supply augmentation options depends not only on price switch per se but also on factors like the ability to adjust consumption within the supply limits as well as the level or magnitude of price change induced by the price switch. When the water rate structure is such that there is only a marginal difference between the marginal and average prices, the price switch, though could provide some incentives for water use efficiency and conservation, may not be sufficient enough to provide the economic scope for the adoption of direct supply augmentation options. To understand the nature and direction of the relationship between price switch and consumption change across various consumer groups, we can use the empirically estimated consumption response functions.

Price Switch and Consumption Response

The empirical estimates of the consumption response function (equation [4]) are reported in Table 10. Since the response function is estimated using a log-log function form, the estimated coefficients are actually the elasticities. Being elasticities, these coefficients indicate how sensitive is consumption change to factors like price change, family size, and housing type. The results show that all the variables have the expected signs in all cases except the lowest consumption bracket. Given our interest in evaluating the level of price change needed to effect a given level of change in metro water consumption, let us concentrate on the size and sign of the coefficient associated with the price change variable in different estimation contexts.

The response function is quite inelastic to price change in all contexts (except the consumption bracket with > 15 cum) in the sense that to achieve a given reduction or increment in consumption, one requires a more than proportionate change in price. Among the two consumption brackets, in the first case, the coefficient is positive because $P^m < P^a$ and hence, consumption change is positive with the price switch. In the second case, since the coefficient is negative and less than one, a given reduction in consumption can be effected with a less than proportionate increase in the price level. This means that consumption change is quite sensitive to price change.

Table 10. Estimates of Consumption Response Function Under Various Estimation Contexts.

Variables	Estimation Context[a]						
	All Cases	*Consumption Bracket*		*Housing Category*			
		Q≤15 cum	Q>15 cum	H=1	H=2	H=3	H=4
Constant	1.806* (24.279)	1.693* (5.215)	1.854* (26.805)	1.861* (5.818)	1.298* (7.870)	1.531* (13.023)	1.480* (9.845)
ΔP	-1.698* (-22.935)	2.904* (11.814)	-0.889* (-49.103)	-1.209* (-4.432)	-1.576* (-15.299)	-1.687* (-12.872)	-1.912* (-10.265)
N	0.737* (5.871)	-0.288* (-2.168)	0.290* (9.374)	0.244 (0.615)	1.031* (5.899)	0.508* (2.458)	0.796* (2.188)
H	-0.916* (-5.558)	0.151 (0.723)	-0.352* (-8.963)	–	–	–	–
R^2	0.803	0.618	0.790	0.483	0.749	0.801	0.863
F-Value	1157.80	313.08	913.34	20.58	510.03	518.98	607.39

[a] Figures in each cell are respectively the coefficient and t-ratio.

* denotes significance at 5 percent or better.

Source: Authors' calculations.

Across house types, the coefficient of the price change variable is negative suggesting that consumption change following the price switch is negative. Notably, since the absolute magnitude of the coefficients increases with the variable H, the required level of price change to effect of a given reduction in consumption declines with the economic/income status of the household. The implication is that economically better endowed households are relatively more price sensitive than others.

But, it is not clear from our estimation results whether the price increase and reduction in consumption due to the switch will be strong enough to provide the required level of incentive for the adoption of supply augmentation options even among larger consumers. This uncertainty is partly due to the marginal difference between the average and marginal prices and partly due to the relatively larger scope for adjusting reduced consumption with simple wastage reduction and use efficiency improvement. It is clear from the analysis of both the demand and response functions that the price switch or change in perception is only necessary but not sufficient to provide incentive for the large scale adoption of supply augmentation and conservation options. The sufficient condition can be ensured only when the price switch is effected within a properly structured water tariff.

ECONOMIC SCOPE FOR SUPPLY AUGMENTATION OPTIONS

To consider still more explicitly the economic scope for the adoption of supply augmentation options, let us evaluate the NWTP calculated for different contexts under both the marginal and average pricing behaviors (see Table 11). Since NWTP is sensitive to change in consumption, it has been calculated assuming various levels of reduction in consumption. The NWTP reported in Table 11 reveals important patterns which are largely in line with our analysis of the demand and consumption response functions.

Table 11. Net Willingness to Pay Under Alternative Pricing Behavior (Rs/cum)

Marginal Pricing Behavior							
Context	Q_1 (Cum)	P^m (Rs/cum)	Elasti-city	Reduction in Consumption (cum)			
				1	3	5	7
ALL	39.391	3.945	-0.580	0.088	0.278	0.488	0.721
Q≤15	10.291	0.928	-0.474	0.106	0.408	0.952	2.199
Q>15	44.308	4.455	-5.343	0.009	0.029	0.049	0.070
H=1	60.604	4.682	-0.495	0.079	0.246	0.426	0.618
H=2	45.206	4.288	-0.718	0.067	0.209	0.362	0.528
H=3	36.369	3.873	-0.559	0.098	0.310	0.546	0.813
H=4	27.040	3.225	-0.547	0.113	0.365	0.661	1.011
Average Pricing Behavior							
Context	Q_1 (Cum)	P^m (Rs/cum)	Elasti-city	Reduction in Consumption (cum)			
				1	3	5	7
ALL	39.391	3.616	0.213	0.226	0.753	1.405	2.224
Q>15	44.308	3.455	3.047	0.013	0.040	0.067	0.096
H=1	60.604	3.912	1.378	0.024	0.072	0.123	0.176
H=2	45.206	3.600	1.751	0.023	0.071	0.121	0.174
H=4	27.040	3.526	-0.667	0.101	0.323	0.579	0.875

Note: The NWTP under average pricing was not calculated for two contexts: Q≤15 (because of unitary elasticity) and H=3 (because of statistically insignificant elasticity estimate).

Source: Authors' calculations.

First is the obvious fact that the higher the reduction in consumption, the higher the value of NWTP in all contexts and pricing behavior.

Second, both in the all-household context as well as among larger water users, the NWTP under the average price is higher than that under marginal price whereas it is the reverse for others. This dualistic pattern is the outcome of the interactive effects of two factors, i.e., the magnitude of difference between average and marginal prices and the difference between the price flexibility of demand (as shown by the inverse of the absolute value of price elasticity) under the two prices.

Third, given the pricing system and quantity change, the NWTP of small and economically poor consumers is generally higher than others. This means that the value of water is higher for smaller users with inelastic demand than others with a relatively more elastic demand. It means further that the economic scope for the adoption of supply augmentation options is more among smaller users than among others. This is in contrast to our expectation because it is the larger and more prosperous groups which actually have all the wherewithal for investing in such supply augmentation options. Still then, the lower value of NWTP under the marginal pricing wherever it occurs does show that the marginal pricing scheme exploits consumers surplus better than the average pricing scheme. This obviously augers well both for revenue augmentation and incentive enhancement.

And, finally, since NWTP measures the value of raw water under the existing water rate structure, its value with a range of Rs. 0.01 to 2.22/cum does not seem to economically justify the inter-basin water transfers requiring an average cost (at source) of Rs. 2.29 to 4.40/cum. This is also the case for privately organized irrigation water transfers either from the ground water or canal areas. This means that for ensuring economic justification for supply augmentation options involving inter-sectoral water transfers, the water rate structure has to be revised along with the promotion of marginal pricing behavior among consumers.

Given the fact that the joint groundwater use from wells has an unit cost of only Rs. 0.55/cum (option 1 in Table 6), there is substantial incentive for joint initiatives in local supply augmentation including inter-household water exchanges even under the existing water rate structure. There is also the scope for the formation of urban water user groups and the evolution of local level water organizations. These institutional initiatives, though require a suitable economic environment, cannot materialize on a required scale without proper supportive policies from the urban water supply authorities. More often than not, most of the local level supply augmentation options--including the most costly one involving water purchase from private tankers (option 11 in Table 6)--which are currently being adopted by some users, happen more because of water non-availability or water inadequacy than because of the economic incentives generated by the existing pricing structure.

In contrast to the long-distance water transfers schemes, most of the local level supply augmentation options involve no or least conveyance and distribution costs. In this case, the willingness to pay rather than the NWTP that is of relevance in evaluating the feasibility of alternative supply options. The role of the pricing scheme in providing incentive for the exploration of and reliance on various technically feasible alternative supply augmentation options can be understood by comparing the cost of these options (Table 6) with the mean water rates under different pricing schemes (Table 7).

Even though there is incentive for some supply augmentation options even under the existing average price scheme (e.g., reliance on own wells and ground water diversion from irrigation especially by households living under flats system as the unit costs of ground water from these sources are far lower than the average price), both the level of incentives as well as the number of feasible supply augmentation options increase with marginal pricing behavior induced under a revised rate structure. This is especially so for users with larger consumption. In view of the substantial difference between the unit costs associated with the alternative supply augmentation options and the applicable P^m, households with higher water consumption (bungalows--either with or without garden--and flats) will find it economically attractive to rely more on own wells and water diversion from irrigation.

Given the presence of substantial mutual economic gains, there is also an enhanced scope for the emergence of inter-household and inter-sectoral water market as well as private initiatives in organising such water transfers on a larger scale. Moreover, a water rate structure with higher rates and marginal pricing behavior could not only provide financial support to inter-basin water transfers but also lend economic justification to additional investment in the rehabilitation and strengthening of the existing storage and distribution systems. As can be seen from Table 7, depending upon the consumption and housing categories, P^m can yield an additional revenue of Rs. 0.32 to 1.00/cum over and above P^a even within the existing water rate structure. As to the relative equity effects of the two pricing schemes, P^m is closer to both the ability and willingness to pay of users as compared to P^a.

It is clear that the pricing option involving revised rate structure could not only improve the financial viability of the HMWSSB but also contribute to the overall sustainability of the urban water supply system as such. Since the pricing option creates a powerful incentive structure for economically activating various technically feasible water supply augmentation options including the one involving water use efficiency improvement (both in urban areas and agriculture), it can also facilitate the emergence of institutional mechanisms necessary for the actualisation of the economically important intra and inter-sectoral water transfers in the urban areas.

CONCLUSIONS AND POLICY IMPLICATIONS

Considering the tremendous pressure that population growth, area expansion, and life style changes could exert on the urban water supply system, water scarcity is likely to continue as major problem for Hyderabad city. Although over-optimistic supply augmentation schemes like the transfer of water from Krishna and Godavari Rivers are expected to eliminate the demand gap by 2021, the reliance on such conventional approaches involving the mere augmentation of supply by tapping new and costlier sources within the existing system of water pricing and water use pattern cannot be a durable solution, at least, for two reasons.

First, given the continuance of wastage and inefficient water use on the one hand and gross subsidisation of water on the other hand, the supply augmentation options presently being considered by HMWSSB will remain to be a financially non-viable proposition in the long-run.

And, second, given the all-round water scarcity across sectors, additional diversion of water—both from surface and sub-surface sources—to urban areas is likely to impinge on the water available for non-urban uses, especially irrigation, creating serious inter-sectoral (and even inter-state) water allocation conflicts.

The incentive environment in the urban water sector can be improved not only by adopting a proper water rate structure but also by removing certain legal and technical impediments to inter-sectoral and inter-regional water transfers occurring especially on private account and voluntary basis. The emphasis should be on the promotion of multiple water sources—both private and public as well as ground water and surface water—so as to relieve the tremendous pressure on the urban water supply and distribution systems. In view of the crucial economic linkages that the pricing option has with various supply augmentation options—both conventional and non-conventional, devising a proper pricing scheme remains central to urban water sector planning and management.

However, our analysis of water demand and response functions under alternative pricing schemes clearly shows that from the viewpoint of promoting the adoption of local level supply augmentation options including in-house water use efficiency and conservation on a larger scale in Hyderabad, marginal pricing scheme, though necessary, is not sufficient due to the inefficiency of present water rate structure.

To ensure the sufficient condition for an efficient marginal pricing, the present rate structure has to be reformed to provide for higher slab-specific rates and more steeper slab structure. While supply augmentation from inter-basin water transfers is inevitable due to a fast growing demand, to economically justify such transfers, the first and foremost step involves the revision of water rates structure and the concurrent promotion of marginal pricing behavior among users. Although the revision in the rate structure itself could induce marginal pricing behavior, for more effective results, consumer education and extension to enhance their information and sensitivity to water scarcity are important. With this economic environment, users--either as individuals or as groups--will be motivated to explore and adopt local level supply augmentation option which are within their economic reach.

When the supply augmentation potential of local level options are exhausted and the supply system becomes more efficient, the bringing of additional supply from inter-basin or inter-sectoral transfer schemes will augment supply without any damage to the incentive environment. While the increased revenue from higher water rates could finance these schemes partially, if not fully, the reduced need for additional supply could minimize the potential inter-sectoral water sharing conflicts and hence, avoid possible delays in the materialization of these schemes.

Although the economic rationale for the policy of setting economic environment right and sequencing various supply augmentation options (including the delaying or reducing the scale of inter-basin water transfers) is clear, the political economy considerations often dictate the pursual of large scale projects as the only solution to the urban water problem in Hyderabad. It is true that this solution has the myopic advantage of being politically expedient as it circumvents the politically sensitive issue of revising water rates.

But, this solution also becomes the epicenter for various other problems with equal political consequences as it only delays but not solves the brewing economic crisis of the urban water sector and the underlying implications for its long-term ability in meeting its service obligations. With the ongoing nation-wide economic reform and liberalization programs and the increasing budgetary conflicts between various economic sectors, the policy of subsidizing the urban water sector with a greater ability to pay for water services cannot be immune from the political criticisms of other equally powerful political groups.

Obviously, a properly created economic environment in the urban water sector could also pave the way for unconventional approaches including water pricing based on "willingness-to-pay" principle and inter-sectoral water markets which are absolutely necessary both to ensure efficient use of available supply as well as to augment additional supply at economic prices. Experience in other countries especially the US (urban water supply in California and Arizona) and Chile (urban water supply in Santiago) shows that reliance on market-based approaches for urban water management improves water use efficiency not only in the urban areas but also in non-urban uses because of the powerful influence of economic incentives. In order to activate various less costly supply augmentation options (including inter-household and inter-sectoral water markets and water saving from efficiency improvement at consumer-end), policy changes aimed at improving the overall incentive environment, therefore, hold the key for urban water scarcity problems.

It is the experience in most urban centers including Hyderabad that consumers are willing to pay higher water charges provided they are assured of adequate and certain supply. It is also the case that unreliable and inadequate water services often cause more serious political problems than those possible from a policy of water rate revision coupled with quality services. The underestimation of consumers willingness to accept a slightly costly but quality service is one of the basic problems in the pricing of most services provided by public utilities including those in the urban water sector. Since the perusal of the economically and institutionally rooted policy options has the long-run benefits from the viewpoint of both the economics and politics of the urban water sector, it is important to initiate them now itself rather than postponing it into the future. This policy prescription applies as much to Hyderabad as to any other urban centers especially in the developing world.

Table A1. Service Area and Population Growth in Metropolitan Hyderabad, 1981-2021.

No.	Identification of Area	Service Area (km^2)	Population (in '000)[a]				
			Census		Projected		
			1981	1991	2001	2011	2021
1.	MCH	169.30	2150 -	3021 *(3.5)*	4103 *(3.1)*	5359 *(2.7)*	6445 *(1.9)*
2.	Municipalities	421.05	529 -	1134 *(7.9)*	1850 *(5.0)*	2481 *(2.9)*	3178 *(2.5)*
3.	En-route Villages, Towns & Shamshabad	116.51	97 -	194 *(7.2)*	267 *(3.2)*	326 *(2.0)*	375 *(1.4)*
4.	Additional Areas	46.30			14	25	135
	Total	753.16	2776 -	4349 *(4.6)*	6234 *(3.7)*	8191 *(2.8)*	10153 *(2.2)*

[a] Figures in parentheses are compound annual growth rates.

Source: HMWSSB (1993:3).

Table A2. Use-wise Unit Water Requirements Used in Demand Projections, Hyderabad, 1996.

	Use Categories	Unit Water Requirements	Basis
(A)	***DOMESTIC USES***		
(1)	Bungalows with Garden	250 lt/capita/day	Household Survey , 1991-92.
(2)	Bungalows without Gardens	215 lt/capita/day	"
(3)	Flats	205 lt/capita/day	"
(4)	Traditional Houses	150 lt/capita/day	"
(5)	Houses in Slum Areas	60 lt/capita/day	"
(B)	***NON-DOMESTIC USES***		
(1)	Major Hotels	820 lt/bed/day	Consumption Data, 1992.
(2)	Other Hotels	180 lt/bed/day	I.S.Code[a] 1172, 1983.
(3)	Major Health Centers	590 lt/bed/day	Consumption Data, 1992.
(4)	Other Health Centers	340 lt/bed/day	I.S.Code 1172, 1983.
(5)	Educational Institutions	45 lt/student/day	I.S.Code 1172, 1983.
(6)	Gardens	80000 lt/hectare/day	Water Requirement Data Collected from Horticultural Department
(7)	Swimming Pools	5 percent	Normal Treatment Plant Make-up Water Capacity for Swimming Pools
(8)	Cinema Theaters	15 lit/seat/day	I.S.Code 1172, 1983.
(9)	Working Populations	45 lit/capita/day	I.S.Code 1172, 1983.

[a] I.S. Code relates to Indian Standard Code as specified by the Indian Standards Institute, New Delhi.

Source: HMWSSB (1993:5)

Table A3. Water Requirement Projections by Area and Use Category, Hyderabad, 1991-2021. (mcm)

Areas	Year	Use Categories			
		Domestic	Non-Domestic	Unaccounted	Total
MCH	*1991*	165	21	47	233
	2001	239	30	68	337
	2011	323	39	93	455
	2021	425	47	118	590
Municipalities	*1991*	64	9	17	87
	2001	109	15	31	154
	2011	160	19	45	225
	2021	224	25	62	312
Enroute Villages & Towns	*1991*	5	1	2	8
	2001	8	1	2	11
	2011	10	1.2	3	15
	2021	12	1.4	3	17
Industrial/Business Units	*1991*	-	27	7	34
	2001	-	42	11	53
	2011	-	58	15	73
	2021	-	75	19	94
All Uses	*1991*	231	58	72	362
	2001	357	87	111	555
	2011	504	118	155	777
	2021	662	149	202	1013

Source: HMWSSB (1993:3).

Table A4. Water Available with Successive Augmentation, Hyderabad, 1991-2021. (mcm)

Water Supply Sources	Availability at Source (now+future)	Losses with Leakage Control Program in[a]			Water Available for Distribution			
		RWT	*WTP*	*CWT*	*1991*[b]	*2001*	*2011*	*2021*
Himayat Sagar	33	0.7	1.8	0.0	31	31	31	31
Osman Sagar	42	0.7	0.7	0.7	40	40	40	40
Manjira Phase I	30	0.0	0.7	1.1	29	29	29	29
Manjira Phase II	60	0.0	0.7	1.8	56	56	56	56
Manjira Phase III	55	0.7	0.7	1.8	50	50	50	50
Manjira Phase IV	55	0.7	0.7	1.1	51	51	51	51
Krishna I	150	0.7	0.7	1.1	-	139	139	139
Krishna II	150	0.7	0.7	1.1	-	-	139	139
Krishna III	150+	0.7	0.7	1.1	-	-	-	139
Godavari	319	0.7	0.7	1.1	-	-	-	296
Water Available after Treatment & CWT Losses					256	395	535	971
Distribution Losses for Feasible Hours					50	62	62	439
Water Available at Consumer end for Feasible Hours of Supply					565	912	1294	2220

[a] RWT = Raw Water Transmission, WTP = Water Treatment Plant, and CWT = Clear Water Transmission.

[b] Water availability without the Krishna option.

Source: HMWSSB (1995b:81).

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