PRICING PUBLIC UTILITIES
: A STUDY OF DRINKING WATER

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TO

AVINASH, APARNA

AND

SREE LATHA

September 2, 1993

I hereby affirm that the research for this dissertation titled ***"Pricing Public Utilities: A Study of Drinking Water"*** being submitted to the Jawaharlal Nehru University for the award of the Degree of Master of Philosophy, was carried out entirely by me at the Centre for Development Studies, Trivandrum.

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Certified that this dissertation is the bonafide work of G Murugan. This has not been considered for the award of any other degree by any other University.

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CONTENTS

LIST OF TABLES

LIST OF FIGURE

Chapter 1

INTRODUCTION

1.1. The Background:

Public utilities can broadly be divided into those providing transportation services and those providing services through physical connection between the plant of the supplier and the premises of the consumers. In the first group, one might include metropolitan transport and solid waste management, and in the second, electricity, cable television, gas, sanitary sewers and telephone services (Schmalensee, 1978). Of these, the water supply systems come under the latter.

The need for good potable water as a prerequisite for a healthy living need hardly be emphasized. "Half the infants that die in the world each year die from water borne diseases. Eighty per cent of all the diseases in the world are water related. Half of all hospital beds in the world are occupied by people with water borne diseases" (Bourne; 1980).

The United Nations conference on Drinking water held at Mar del Plata, Argentina, from 14th to 25th March 1977, adopted a resolution recommending a long and detailed plan of action on community water supply and sanitation. 1980 to 1990 was designated as the `International Drinking Water Supply and Sanitation Decade' with the following targets:

i. 100 per cent coverage of all urban areas with drinking water supply system;

ii. 100 per cent coverage of all rural areas with potable water supply facilities;

iii. 100 per cent coverage of all class A and B cities and eighty per cent coverage of all other towns with sanitation facility; and

iv. 25 per cent coverage of the rest of the country with sanitation facility[1].

India, being a signatory to the conference, is under moral obligations to satisfy the said targets. Provision of water supply comes under the state list of the constitution and the responsibility to achieve the targets remain largely with the state governments. But, even in a state as Kerala which inaugurated its massive water supply scheme as early as 1933, these targets remain largely unfulfilled; as late as 1992,the coverage of water supply has reached only up to 65 per cent of the urban population and a little over 40 per cent of the rural.

It may be surmised that this low coverage has resulted, by and large, from the utilisation of resources for the maintenance and operation of the existing systems rather than on new schemes. The existing schemes are not able to generate adequate funds for their survival, demanding extra funding by the State. In this context, the urgency of a suitable pricing policy needs no special emphasis. The prices chosen should cover at least the break even cost. In other words, the total revenue collected from the consumers\ groups of consumers by means of water charges should cover the total cost. But, this need not always satisfy equity considerations. Therefore

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[1]. See U.N. (1977).

the element of welfare maximisation with equity should be incorporated while pricing the water utilities.

It is in this specific instance, that we examine the Trivandrum Water Supply System (TWSS). This was started by the erstwhile Travancore Government in 1933 with a capital investment of Rs. 8125990/- and with an installed capacity of 4.5 million gallons per day. In the early stages of its operation, it was generating adequate resources not only to finance its operation and maintenance, but also for its future expansion[2] (Table 1.1).

Table - 1.1

Revenue and Expenditure, 1939 to 1943
(Trivandrum Water Supply System)

Year	Water Works Receipts(Rs)	Expenditure on Maintenance(Rs)	Surplus Rs.
1939	83012	48241	34771
1940	91110	41519	49591
1941	126996	50313	76683
1942	129766	50991	78785
1943	143919	45575	98344

Source: Government of Travancore, Administration Reports, Water works and Drainage Department, (various Issues).

In the post independence years the situation changed. Unfortunately separate data on TWSS are not available. However, those pertaining to all water supply systems in the state indicate that the tradition set by the TWSS in the pre-independence period was altered and water became increasingly subsidised by the state (Table 1.2).

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[2]. Government of Travancore, Administration Report of Water Works and Drainage Department, 1940.

Table 1.2

Revenue and Expenditure on Water Supply and Sewerage

(Rs.Lakhs)

Year	Revenue receipts	Expenditure	Revenue Deficit
1960-61	0.28	7.82	- 7.54
1965-66	13.30	22.92	- 9.62
1970-71	30.31	34.88	- 4.57
1975-76	68.30	111.17	- 42.87
1980-81	205.04	419.61	- 214.57
1985-86	1428.60	2281.56	- 852.56
1987-88	1681.04	2969.78	- 1288.74
1988-89	1714.02	3423.34	- 1709.32
1989-90	3156.00	4672.00	- 1516.00
1990-91	1828.0*	5905.0*	- 4077.0*
1991-92	1864.1@	5702.0@	- 3838.0@

Notes: * Revised estimate of the Budget and @ Figures as per Budget estimate.

Sources: 1) Government of Kerala, Budget documents, (various issues).
2) Kerala Water Authority, Budget document, (various issues).

This buttresses the need for a proper pricing policy which can reduce the level of subsidy.

Hardly any study exists in India for the proper pricing of the water supply systems. `The questions of interest for water resource planners in most developing countries are, however, quite different from those planners of industrialised countries, and the uncritical transfer of methods and results of water demand studies from industrialised countries to developing countries has, in our opinion, been a serious error' (Xinming Mu, Whittington and Briscoe; 1990).

1.2. Objectives of the Study:

The main objective of the study is to evolve a methodology for determining the rate structure with cross subsidy for water utilities with a case study of Trivandrum Water Supply System. More specifically, the study involves:

i. Statistical analysis of cost functions using time series data collected from books of accounts of Kerala Water Authority (KWA). It involves a plant wise and aggregate estimation of cost functions and an analysis of the impact of different technologies on the cost of production;

ii. The estimation of demand functions from a random sample of 555 consumers. It also attempts to construct an Adult equivalent Scale and to identify the socio-economic variables that influence water demand; and,

iii. To develop a set of prices for different groups of domestic consumers so as to recover break even cost.

1.3. Outline of the Study:

The study begins with the need for a rational pricing policy for a public water utility, followed by a brief review of the relevant literature on pricing of public utilities. Chapter - III discusses the data and its measurement problems. Chapter - IV is broadly divided into two sections. The first deals with the Plant wise analysis to highlight the impact of technology on cost of

production. The second gives an aggregate cost function which is used to arrive at the rate structure. Chapter V is on the socio economic determinants of water demand, using Adult equivalent scales. The penultimate chapter develops alternative models of rate structure with cross subsidy, based on consumption and income criteria. The last chapter summarises the final results and discusses the policy implications of the findings.
Suggestions for further research have also been made here.

Chapter II

LITERATURE – A SURVEY

Introduction:

Different theories of Public Utility analyses the problem of pricing with different perspectives depending on the situation. They consider the political scenario and the economic situation of a country which predominantly determine what should be the pricing pattern. The pricing pattern and the relevance of it changes according to commodity or service which requires to be priced. Unlike the profit maximization principle, there exists a synthesis of both revenue maximization and welfare maximization in public utility pricing. It shall be very difficult to apply one set of theory itself to different countries and different regions. Hence, only a well thought out formulation of the pricing system can fetch a combinatorial maximization of both revenue and welfare. In this chapter a bird's eye view of some of the existing theories and studies are given so as to provide a conceptual basis for this study.

Section I

2.1.1 The Marginal Cost Pricing:

The theory of marginal cost pricing describes the setting up of price for a particular product - public good - equal to the marginal cost (MC) of producing it. Pareto optimality conditions state that price equal MC gives a maximum possible social welfare.

According to professor Baumol and Bradford (1970), "In an economy in which industry has been nationalized and maximization of social welfare is aimed at, all prices must be set equal to MC and deficits if any, made by the state subsidies". Then the question is how long can the government subsidize, especially in states with lesser resources and comparatively larger needs? It also brings forth the question, as to what extent the state should subsidize when the resources itself are limited.

Economists are of the argument that price equals marginal cost always maximize welfare wherein marginal cost is assumed to be constant and total cost will equal zero at q=0. The problem of maximizing social welfare 'CS + Ps' is ,(where Cs is the consumers surplus and Ps is the producers surplus).

$$CS + PS = \int_{p_0}^{qa^{-1}(0)} q(p)\ dp + \int_{q^{-1}(0)}^{p0} sp\ dp$$

$$\text{where in } Cs = \int_{p_0}^{qa^{-1}(0)} qp\ dp$$

$$\text{and } Ps = \int_{mc_0}^{mc^0} s(p)\ dp$$

$$\text{and } TR + CS = \int_0^{q0} p(q)\ dq$$

This ideal conditions of the system are very difficult to exist even in a highly efficient and systematically managed public utility.

2.1.2 Ramsay Pricing or Pricing the Second Best:

The theory of marginal cost rules where price equals marginal cost, leads to the first optimal pricing situation whereby social welfare is at it's optimum at that point. Hence, under public utility pricing, the pricing is subject to an additional constraint that the firm must set for break even. Since the break even constraint prevents the imposition of the fully optimal so called first best marginal cost prices, the prices which maximizes total surplus subject to break even is referred to as the optimal second best. However, this ignores the capacity and willingness to pay of the consumer leading to only a partial view of the situation. The partial view of the things from the firm's side completely ignores the demand aspects.

2.1.3. The Third Best Pricing Rules

In this pricing rule Danielson, Kamerschen and Keenan (1990) brings in an intermediary stage. According to them, looking at the manner in which utility rates are actually established, there is typically an intermediate stage between the determination of the overall revenue requirement and rate design. This stage is generally referred to as the revenue allocation process, whereby the cost to serve is distributed among various customer classes e.g. residential, commercial and industrial. It is only after class revenue responsibilities have been assigned the rates within each customer class are established to meet the class revenue requirement. Thus, just as meeting the overall revenue requirement is a constraint on optimal pricing, the revenue allocation process may be regarded as yet another constraint.

The overall revenue requirement is primarily determined by

i. What expenses including taxes, should a public utility firm is expected to recoup from it's customers?

ii. What is the value of the properties used and useful in providing service?

iii. What is the appropriate capital structure and how rapidly should the firm recoup the funds provided?

iv. What minimum, maximum or optimal rate of return should investors receive on funds that remain devoted to the enterprise?

Only after resolving such questions, the firm will be in a position to address the question of what specific rates will yield the overall revenue requirement. A primary objective of the traditional "fair return" regulation is the requirement that a company is entitled to establish rates such that expected revenues as a whole cover the nature of expected costs. However Danielson, Kamerschen and Keenan (1990) argue that the pre assignment of class revenue responsibility poses a problem because the sum of these revenue allocations will exactly match the overall revenue requirement only under special and unlikely conditions. In fact, the revenue requirement will be met exactly only if total costs are fixed or all demand schedules are perfectly inelastic. Actual revenue allocation procedures have historically been treated as perfectly demand inelastic, but if this were true there would not be a revenue allocation or rate design problem. Rates could be assigned arbitrarily to any service with no effect on quantities demanded and with the assurance that costs would be covered.

However, if the assumption of perfect inelasticity is empirically invalid, which in general it will be, then using it as a basis for establishing class revenue responsibility will lead to a failure to meet the overall revenue requirement. This is the dilemma in assigning absolute revenue responsibility to customer classes. Thus a more precisely valid or consistent regulatory practice calls for the selection of class revenue allocations that depend on the actual aggregate costs that will be experienced in light of actual demand elasticities. But in the case of drinking water though there exists inelasticity to some extend, as the demand is not purely for drinking purpose alone, one cannot fully conclude an inelastic demand for water.

The revenue allocation expressed in absolute terms will lead to a rate design problem of the form

$$\underset{p}{\text{maximize}} \quad W\,[x(p)]$$

such that

$$R^j\,[x(p)] = \bar{R}^j \qquad , \; j = 1 \ldots\ldots m$$

where, in a hypothetical case the revenue responsibility $\bar{R}^j$ of each customer class j among m classes is set at the Ramsay second best levels $\hat{R}^j$.

The first order condition characterizing this problem is that

$$\delta W / \delta p = \sum_{j=1}^{m} l^j \quad \delta \bar{R}^j \,/\, \delta p$$

which under the usual assumptions gives

$$- \alpha xi = 1^{j} \ (xi + pi \delta xi / \delta pi) \quad \text{for } j = j(i)$$

so that rearranging terms we have

$$\varepsilon i = K^{j(i)}$$

Where $K^{j(i)}$ means the Ramsay number of the class 'j' to which the given 'i'th good belongs. Unlike the classical second best problem, Ramsay numbers now vary across classes, though still not within a class. It is immediately apparent that the Ramsay outcome would be achieved only if it were to lead to an equal percentage of marginal cost pricing rate within each class, though this would by no means be a sufficient condition.

The obvious way to achieve consistency is to apportion class revenue responsibility on the basis of actual costs, that revenue allocation consists of distributing the common cost to serve. Formally each customer group 'j' is assigned to raise enough revenue to cover their assigned share of costs, C^{j} [x(p)] as indicated by the revenue allocation process. The rate design problem then becomes

$$\underset{p}{\text{maximize}} \ W(p)$$

such that

$$R^{j} (p) = C^{j} [x(p)] \quad , \ j = 1 \ldots\ldots m,$$

where the requirement that total costs be covered by class shares.

$$C\ [x(p)] = \sum_j \overline{C}^j\ [x(p)]$$

assures consistency. However, even here cross subsidization is still permitted between classes, since the revenue responsibility of any given class need not respond to it's actual contribution to total costs. Also another important factor is that no assumption has been made about the actual cost function C(x) other than the usual condition that marginal cost pricing leads to revenue deficiency.

Under the usual assumptions mentioned earlier in the classical Ramsay analysis, the solution takes the form

$$(pi - \Sigma\ ((l^j\ /\ lj(i)\ )M\overline{C}^j{}_i\ ))\ /\ pi = K^{j(i)}\ /\varepsilon\ i$$

where $M\overline{C}^j{}_i$ is the marginal effect of the 'i'th service on class j's cost share, l^j is the multiplier of the 'j' th constraint and j(i) represents the customer class associated with the 'i' th service.

This solution satisfies the criterion of consistency, as well as the desired condition that the cost shares were assigned in conformity with the classical Ramsay outcome.

Defining $\overline{\pi}^j = R^j - \overline{C}^j$, each multiplier $l^j < 0$ represents the effect $\delta W\ /\ \delta\overline{\pi}^j$ on welfare of tightening the 'j' th allocation constraint, and the Ramsay type number K^j is related to this by

$$K^j = (l^j + \alpha)\ /\ l^j$$

with W interpreted as the indirect utility of a representative consumer. Using Roy's lemma $\alpha = \delta W / \delta y$. Then, since manipulating the prices to raise a rupee that is subsequently returned lump sum to the consumer will nonetheless leave the person worse off. We can be certain that $l^j + \alpha < 0$ and hence, $K^j > 0$. Thus, the price of each service will exceed its marginal cost as in the classical Ramsay case.

These observations suggest an iterative scheme by which revenue allocation process may operationally be made to converge to the classical Ramsay outcome. The cost shares of those classes with the highest Ramsay numbers ought to be raised and those of the other classes lowered. This will transfer revenue responsibility to where it has the least deleterious effect, thus raising welfare.

The proposed problem takes its most transparent form when costs are of the additive form.

$$C(x) = C_0 + \sum_i C_i (x_i)$$

so that total cost consists of the separate variable costs of individual services all added up, together with a fixed cost term C_0 . Then it is natural to choose

$$\vec{C}^j (x) = \vec{C}^j_0 + \sum_{j(i)=j} C_j (x_j)$$

which indicates that the 'j' th class cost share is to be the added cost of all services used by that customer class together with some assigned share of the fixed costs i.e.

$$\sum_j \overline{C}^j_0 = C_0$$

In this case the pricing rule reduces to

$$(p_i - MC_i) / p_i = K^{j(i)} / \varepsilon_i$$

so that in this the only deviation from Ramsay pricing is that K^j depends on the customer class. The combined assumptions of independent demand and additive costs have decoupled the rate design into separate classical Ramsay problems within each class. The prices of all services within each such class are raised proportionately over their marginal costs until sufficient revenue is raised to meet that class responsibility.

2.1.4. Fully Distributed Cost Pricing:

This consists of a whole set of approaches of allocating common costs and services. Once this allocation is done, prices are set so that such set of services just covers it's fully distributed cost.

Fully distributed cost = Attributable cost of 'i' +'fi'≥ common cost, wherein 'fi' is the fraction of the common cost attributed to service 'i'. This too has certain limitations, in the context of drinking water in underdeveloped countries since it is assumed that all assets are valued at replacement cost and the common cost is treated as fixed cost 'F'.

2.1.5.The Game Theoretic Approach to Cost Allocation:

Many regulated firms have a high ratio of common costs to attributable costs, which leaves a large degree of indeterminacy in setting prices. This fact leads frequently to the allegation of cross subsidy. Consumers dislike higher prices and are often on the look out to see that the services they use are not cross subsidizing some other service. The fringe of competitive suppliers facing the regulated firm has the opposite concern; it dislikes low prices and is apt to appeal to the regulatory authority that it is the victim of predatory pricing. But together these groups can often muster considerable political muscle behind the argument that consumers of regulated firm cover less competitive services are paying excessively high prices to subsidize predatory pricing in the regulated firm's more competitive markets. Hence some economists of 70's developed a rigorous theory of cross subsidy to compute prices based on the theory of co-operative games. The theory attempt to define carefully what is meant by cross subsidy, to compute prices which do not cross subsidize or are subsidy free, and to provide tests for whether or not given prices are subsidy free.

The simplest kind of game may be is one which the 'N' players can be thought of as consumers attempting to be served at minimum cost. Thus off peak and peak services will be considered as different players. Assuming that demands are completely price inelastic, the outputs for each player are fixed. Suppose that there are 'N' players and a cost function C(s) which gives the minimum cost of serving a coalition 's', where 's' is a sub coalition which can be formed out of 'N' player coalition. All possible sub coalitions 's' are continually considering whether or not to defect from the grand coalition and be served by a specialty firm using the same technology as the monopolist. Faulhaber (1975) defined C(s) as the stand alone cost of coalition 's' in the grand coalition 'N'. The sub coalition 's' cannot be charged more than it's stand alone cost. Let 'ri' , $i \in s$ be the price paid by any member of sub coalition 's' to belong to 'N' to prevent 's' from defection.

$$\sum_{i \in s} ri \leq C(s)$$

for every possible 's' that can be formed out of 'N'. In addition the monopolist serving the 'N' players must break even

$$\sum_{i=1}^{N} ri = C(N)$$

When both these sets of constraints are met, then no sub coalition 's' would like to break away from the grand coalition 'N' and be served at a lower cost. In game theoretic words, when a set of prices r1, r2, ...rn satisfies the constraints 2.1 and 2.2 they are at the core of the cost game.

Putting it alternatively

$$\sum_{i \in s} ri \leq C(s)$$

Let all other consumers be N-s and the stand alone cost C(N-s) then the break even constraint would be

$$\sum_{i \in s} ri = \sum_{i \in N-s} ri + \sum_{i \in s} ri = C(N) \quad \sum_{i \in s} ri > C(N) - C(N-s)$$

2.1.6 The Axiomatic Approach to Cost Sharing Prices:

This theory of pricing is not concerned directly with the economic effects of different allocation schemes but it begins by listing intuitively desirable features of any allocation of schemes. Taking these desirable features as axioms the features of prices are deduced, which are consistent with the axioms. The precise axioms that one writes down depends in part on whether the firm's cost function has a positive fixed cost or not. The fixed cost issue is in turn determined in part by whether one is dealing in the short or long run. The time periods that are relevant for regulatory auctioneer is usually quite short, so that one can never be sure that the firm's cost function is that which minimizes total cost at current output (Brown and Sibley; 1986). Mirman, Samet and Tauman (1983) discuss this point and present six axioms for cost allocation where the cost function is not assumed to represent the long run efficient technology for the given level of output and where a fixed cost is present.

For this analysis a joint cost function 'C' is envisaged, where

$$'C' = F + V\ (Q1, Q2.........Qn).$$

V (Q1,Q2---------Qn) is the variable cost function of the firm i, it depends in a general way on all N of the firm's outputs. There are assumed to be no set up costs for each service. For simplicity let us denote the list of outputs Q1,Q2......Qn simply by Q and the total cost function by C = F+V. Let P be the set of prices P1,P2.....Pn Mirman, samet and Tauman proposes the following axioms.

axiom 1 Cost sharing: An allocation mechanism which results in prices P for given set of outputs Q and cost function C must cover it's total costs.

axiom 2 Re-scaling: if the scales of measurement of the commodities are changed, then a sensible allocation mechanism should result in prices P which change accordingly.

axiom 3 Consistency: Suppose for a sub set m of output costs depend only on total output costs (M c C) depend only on total output Q1,Q2.....Qm , then the prices of any two output in 'm' should be the same.

axiom 4 Positivity: Consider two alternative cost functions C and C^* where $C \geq C^*$ at zero output and the cost difference $C - C^*$ increases as outputs rise. A sensible allocation mechanism should result in higher prices under C than under C^*.

axiom 5 Additivity of allocations: Suppose that the cost of producing a given set of outputs Q = (Q1,Q2.......Qn) can be separated into K different "stages" each with it's own variable cost GK(Q) where K labels the stage. Thus V(Q) is the sum of costs from the K stages.

V(Q) = G1(Q) + G2(Q) + ...GK(Q).

Then the allocation mechanism should assign a fraction fK of the common cost to each stage and the allocation fKF should be added to each stage's variable cost. Also total revenue of each stage's cost.

$$\text{Total revenue (TR)} = \sum_{K=1}^{K} [GK\ (Q) + fKF]$$

axiom 6 Correlation: For any two stages K and 1 if GK > G1 then fK > F1.

It is argued by many authors like Brown and Sibley (1986) that there are certain limitations to this form of pricing strategy. However, there is no relevance for this theorem to our study.

2.1.7 Peak Load Pricing:

Peak load pricing is also a differential pricing wherein different charges are made for peak consumption and off-peak consumption. For simplicity, if we assume a single type of plant with the short run marginal cost, operating and maintenance cost given by the constant 'a', and the long run marginal cost of adding to capacity given by the constant 'b', then the pressure on capacity arises due to peak demand, while the off-peak demand doesn't infringe on the capacity. The optimal pricing rule now has two parts corresponding to two distinct rating periods.

(i) the peak period price = a + b

(ii) the off peak period price = a.

The logic behind this form of pricing is that peak period users, who are the causes of capacity additions, should bear full responsibility for capacity costs as well as operating and maintenance costs while off-peak consumers only pay the latter costs.

Certain countries like Israel have adopted the peak-load pricing system for drinking water supply. Empirical studies conducted in Israel show that substantial reduction in the quantity of consumption took place. This leads one to the conclusion that the water demand was not the real demand for drinking purpose but for many other purposes which would have got reduced and that has contributed for the ultimate reduction in the total consumption as the prices itself are higher. Of late, the Kerala State Electricity Board also adopted this method of pricing for their extra high tension consumers. Separate metering is introduced for this purpose by the electricity board. Where the peak load prices are followed in water supplies, it calls for considering the climatic situations to charge the price. The prices during summer months in an year is higher than that of it in winter.

2.1.8 Two Part \ Multi Part Pricing Scheme:

Under the two part system the total rate charged is divided into two portions. Each consumer is charged a fixed fee 'A' per unit period plus a constant marginal price per unit. All consumers are charged the same fee and price per unit. The objective of the enterprise is to find the price P and the fee 'A' that will maximize the weighted total net social welfare subject to the budget constraint and the income of the poorest. The optimal prices may be arrived at by maximizing

$$W = N \int_{Y1}^{\infty} [s(P,Y) - A]\ U'Y\ f(Y)\ \delta Y$$

subject to

$$PQ + NA \int_{Y1}^{\infty} f(Y)\ \delta Y = CQ - B = 0$$

and $S\ (P,Y) = A$

where by definition

$$Q = N \int_{Y1}^{\infty} Q(P,Y)\ f(Y)\ \delta Y$$

2.1.9 The Declining Block Pricing:

The declining block pricing scheme varies from the two part pricing, wherein each consumer is charged the same fixed charge A, but differing prices. It is a variant of two part tariff scheme which tries to maximize consumers surplus by differentiating consumers with their levels of income. A high price P1 may be charged for quantities consumed not exceeding Z units, a low price P2 for units more than Z. Z is a variable set by the enterprise. If we assume that demand for the product increases with income, three different categories of consumers can be distinguished.

i. Households with income ranging from 0 to Y1 who prefer not to buy the product.

ii. Households with income ranging from Y1 to Y2, this group buy < Z units.

iii. Households with income ranging from Y2 to Y3 and who should be purchasing > Z units.

The rationale is that as one go on consuming more units his per unit cost will be decreasing.

2.1.10 The Inverted Rate Pricing Scheme:

This pricing schedule is in a way the reverse of declining block pricing. In this method of pricing a low price P1 rather than a high price is charged for quantity consumed < Z units. Similarly, for quantities demanded more than Z units, a higher price P2 is charged. (These prices are the fixed charge A, per period). With this four distinct consumer groups can be identified.

i. Group with income ranging from 0 to Y1, that buys none of the product, or willing to accept the product only if the service is given free of cost to them, or may be the group who doesn't have the capacity to pay.

ii. Group ii with incomes ranging from Y1 to Y2 that buy < Z units.

iii. Group iii with incomes ranging from Y2 to Y3 that buy exactly Z units.

iv. Group iv with incomes ranging from Y3 to α that buy more than Z units.

The price is to be drawn in such a way that it should take into consideration of the consumers surplus, which is

$$S\ (P,Z,Y) = \int_0^Z PQ\delta Q - P1Z \qquad b-1/b$$

$$= a1/b\ b1/b\ Z \qquad b/b-1-P1Z$$

Denoting by Q1, Q2, Q3, the total quantities demanded by groups 2,3 and 4 respectively, the optimal prices will have to maximize the total welfare, which is

$$W = N \int_{Y1}^{Y2} [S(P,Y) - A]\ U\mu\ (Y)\ fY\ \delta Y +$$

$$N \int_{Y2}^{Y3} [S\ (P,Z,Y) - A]\ U\mu\ (Y)\ f(Y)\ \delta Y +$$

$$N \int_{Y3}^{Y*} [S\ (P,Y) - A + (P2-P1)\ Z]\ U\mu\ (Y)\ f(Y)\ \delta Y$$

subject to

$$P1Q1 + P2Q2 + P2Q3 + (P2-P1)Z \quad N \int_{Y}^{*} f(Y)\ \delta Y + NA$$

$$\int_{Y1}^{*} f(Y) - C\ (Q1+Q2+Q3) + B = 0$$

i.e. $P1Q1 + P2Q2 + P2Q3 + (P2-P1)\ Z\ \ N \int_{Y3}^{*} f(Y)\ \delta Y +$

$$NA \int_{Y1}^{*} f(Y)\ \delta Y -$$

$$C(Q1+Q2+Q3) + B = 0$$

$S(P,Y1) = A$

$Q(P1,Y2) = Z$

$Q(P2,Y3) = Z$

The above model is meant for a static situation wherein instantaneous price movements in the raw materials and components that are going as inputs into the system makes effective changes in the system of prices also. Yet it may not be a true case in an underdeveloped country like India. However a dynamic analysis may implead the lag system of equations to the system. Changes in input prices should obviously be taking place, in any system as they are mostly market determined clearly acting upon the market forces of supply and demand and the nature of the product. Despite this the constraints imposed on such enterprises, producing public goods and the nature and necessity of the product or service, that is being made available to the consumer prohibit the enterprise to accommodate for the increase in input prices of raw materials by hiking the price of their product. A dynamic analysis of the situation may bring in some results that could accommodate for such changes in raw material prices. However, such an attempt has not been made in this analysis due to severe data constraints.

Section II

2.2.1 Literature on Indian Situation:

Hardly any study exists on the pricing of water supply systems to the Indian situation. Some of the literature that are available are only studies conducted by some consulting agencies for some of the state governments. there is neither any economic rationale nor any theoretical basis for such studies, except to satisfy the donor agencies.

The study conducted by Tata Consulting Engineers (1992) for the three municipal corporations of Trivandrum, Cochin, and Calicut and another study on Cost and Revenue carried out by M/s. A.F. Furgusson & co., for the government of Kerala are some among them to the Indian situation. Since the above studies consider the Trivandrum water supply System let us examine the recommendations and observations in that. On a careful scrutiny, these studies are found to be incorrect in approach and specification. The study conducted by Tata Consulting Engineers for Trivandrum makes the recommendation that cross subsidy is envisaged between domestic and non domestic consumers by designing the rates in the manner they have recommended. in the same study itself they analyze and bring to light that almost 84 percent of the total quantity of water produced in Trivandrum is consumed by the household sector and only the balance is distributed for the non household consumers. Even if an abnormal price is charged from latter two groups, it shall be impracticable to bring in such cross subsidy between consumers.

The cost study of A.F. Furgusson & co also gives a distorted picture. According to their study the water supply to Trivandrum city works out to only 39 million litres per day and the costs are estimated based on that. If their estimates are true and accepted, the basis of the investment in Plant II is unwarranted at least partially. But in the actual situation despite the increased capacity the Trivandrum Water Supply is running short of adequate water to distribute. All these have taken place because these studies are not indepth and systematic. The above observations on the studies of Trivandrum water supply shall provide the necessity for this study.

Chapter III

DATA SOURCE AND METHODOLOGY

3.1. Introduction:

The analysis of pricing requires the expenditure incurred in the process of production. The type of cost incurred by water utilities are generally classified as fixed and variable costs. While the fixed costs are the expenditure incurred for the construction of the capital equipments, and plant & machinery etc., the variable costs are essentially incurred for the operation and maintenance. The latter includes (a) acquisition facilities (b) treatment facilities and (c) delivery systems including transmission and distributions.

The data on the fixed costs and variable costs have been compiled from the records of Kerala Water Authority. However, these data were not available as the analysis require and hence, it took some time to reshape it. The components of cost data are broadly classified into five. The components are (i) wages and salaries, (ii) electricity, (iii) chemicals, (iv) administrative and miscellaneous expenses, and (v) repair and maintenance of plant and building.

The total fixed assets of Trivandrum Water Supply System (TWSS) are of different vintage and based on two types of technology. The plant constructed during 1933, augmented during the 60's followed one technology and the later additions since 1973 adopted a different technology. Of these, the former one takes advantage of the peculiar geographical location. The later additions since 1973 are both capital and energy intensive. Hence, the cost estimate is divided into two, that is of plant I for the period from 1972-73 to 1991-92 and of plant II from 1974-75 to 1991-92. Required data prior to the period of 1972-73 were not available despite a thorough scanning of the Kerala Water Authority (KWA) sources in respect of Plant I. Cost data on Plant II was computed only since 1974-75, although formally the plant started functioning from the latter half of 1973, as the effective functioning of it started only from that period.

3.2. Data on Cost:

The Trivandrum Water Supply System (TWSS) incurs cost for the operation and maintenance, which can be broadly divided into (a) the production costs and (b) the distribution costs. The production cost is the cost incurred till the treated water reaches the storage tanks for distribution which includes the cost incurred in the process of treatment of raw water such as labour, power charges for pumping, chemicals for treatment process, periodic replacement of filter media, and other miscellaneous administrative cost. The distribution costs are the cost incurred for the maintenance of the transmission main and the distribution lines. The cost incurred for the collection of revenue charges from the consumers is also included under the distribution cost.

3.2.1. Wages:

Accounts in respect of wages are not available separately. The same are clubbed with some other offices. Hence apportioning the same was carried out using the installed capacity ratio. The amount of wages not only include salaries and wages paid to staff, but the bonus paid, uniform allowance, washing allowance, overtime allowance, holiday wages, etc. Proportionate allocations have been made for the salaries and wages of the staff engaged in revenue collection according to the allocation methods followed for the different time periods. The accounts maintained by the Public Health Division of the KWA in respect of wages is having the total figures consisting of both the TWSS and some of the Rural Water supply projects for the periods from 1974-75 to 1983-84. As a separate sub-accounts were available for the rural water supply systems, it's operation and maintenance have been totally excluded from the data. From the balance, which is exclusively for TWSS, 20 per cent of the total expenditure is allocated to supervision charges of the Division office, 40 per cent of the wages have been taken towards the wages of the entire operating staff of plant-1, and the remaining 40 per cent have been accounted for the salaries and wages of the distribution staff and the supervisory officers connected with the distribution. The supervision charges of the Executive Engineer's office, the allocation of 20 per cent and that of the distribution system have been redistributed to both the plants according to their capacities that is 3/7 for Plant-1 and 4/7 for plant-2 which existed during each year.

However, the wages of officers above the rank of Executive Engineer has not been considered as their effective allocation of time for the supervision of the maintenance is quite negligible. Most of their time is devoted for the formulation and execution of new projects than on the maintenance of existing ones.

3.2.2. Electricity:

The KWA authorities has the record of the payments made towards power charges to the Kerala State Electricity Board (KSEB) for plant-II and a portion of power charges paid towards the booster pumps for plant-I together. The actual power charges paid by the KWA towards power charges in respect of plant-II and the corresponding units of power consumption was collected from the KSEB and this was accounted towards the power charges of plant-II. The balance amount was allocated and accounted towards the power charges of plant-I, along with the power charges actually paid by the concerned sub-division offices for plant-I, at Vellayambalam for it's production and pumping. In both the cases, the nominal quantities of power used for yard lighting has been accounted for as they are found to be inseparable.

3.2.3. Chemicals:

The expenditure on chemicals constitute not only the chemicals used at the time of treatment of raw water, but also the chemicals used for pre-chlorination of raw water before treatment during summer days and acute drought to take care of the presence of "Chironamus" infection in raw water. Since 1984-85 onwards the purchase of chemicals for the whole TWSS was arranged from one office and the payments was made together. Hence, it was very difficult to decipher the actual consumption of both the plants separately. The portion of the chemicals used has been taken according to the quantities of water treated in both the plants. There seem to have an abnormal hike in the consumption of chemicals since 1984-85. Therefore, averages have been taken for the periods two years prior to the formation of KWA and two years after to normalize the cost of chemicals used.

3.2.4. Administration:

The expenditure under this category was available separately for each of the plants and there were not much problems of allocation and related issues. Hence, those figures have been taken as such. This costs consist of office expenses, stationery charges, postage,telephone charges, printing, fuel charges, repair of vehicles and other miscellaneous expenses.

3.2.5. Maintenance of Capital and Building:

Under this head the repair and maintenance of machinery , electric motors, pumps, replacement of parts etc. have been accounted including wages if the work has been carried out through outside agencies. The maintenance of street pipes, distribution mains trunk mains etc., are also included in this category. The maintenance of building covers expenditure incurred for the maintenance of tanks, office buildings etc; excluding infructuous expenditures like maintenance of guest houses. The periodical washing and cleaning of the storage tanks has also been included under this category.

3.3.1. Output - PLant 1:

Authentic records on output were not available in respect of plant-1. Though venturi meters[1] have been installed in the plant, all of them is not working and, hence, it was not possible to compute the production of this plant from these meters. The same would be obtained from some records and registers pertaining to this plant, but for being lost, it required to be estimated.

The data on actual measurements by the KWA engineers are available for two points of time, namely 1972-73 and 1991-92. Assuming the production till 1972-73 is at the full capacity of the plant I that is 36 m.l.d, the production of plant I has been estimated by making use of the energy input data, which gives an approximate idea of the rate at which the production took place. The energy consumption has been taken as a good measure of the estimation of production for the reason that it is actually measured each month by the electricity board. The actual production measurements at two end points 1972-73 and 1991-92 are actually measured by the KWA engineers. The energy intensities at two end point periods have been worked out using the following.

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[1] . Venturi meters are meters installed in all the water supply systems to measure the flow of water from the treatment plant to the trunk water carrying mains. They give accurate records on an hourly basis. With the help of graphs plotted in the venture meters, it shall be easy to measure the daily flow and thereby the output.

$$EI = Output / units of power consumed.$$

where

EI is the energy intensity at the end points.

Thereafter, the compound growth rate of production have been worked out between the period 1972-73 and 1991-92. Henceforth, the energy intensity for each year have been estimated. As mentioned earlier, the energy intensities for both the initial year and the terminal year are available. Using the initial year as the base, the following equation has been formulated to find out the energy intensity.

$$EI_t = EI_{t-1} + (EI_{t-1} * CGR)$$

Where

EI_t = Energy Intensity at time t

EI_{t-1} = Energy intensity during the previous year

CGR = Compound growth Rate.

The output of the plant has been estimated by making use of the following equation.

$$O_t = EI_t * POW_t$$

Where

O_t = output at time t

EI_t = Energy Intensity at time t

Pow_t = Quantity of energy actually consumed at time t.

Thus, by making use of the energy intensities during each year, the actual use of energy by the booster pumps have been worked out, considering the efficiency loss that could have occurred due to the continuous working of these pumps. The compounded growth rate, worked out depicts a picture of the efficiency loss in the carrying capacity of the raw water conveyance main which took place over years. Here again as 't' approaches 'n' the quantity of energy consumed also progressively increases. Allowances for efficiency loss of pumps due to it's continuous running over a long period has not been accounted for, as they are found to be negligible. This may probably be a lacunae in this analysis, however, in the context of non-availability of direct measures for the production data, the estimated output becomes relevant. From the above estimated production a reduction of 2.5 per cent have been provided to account for the plant losses by way of back washing and filter cleaning in the plant etc.

3.3.2. Plant - 2:

The actual daily pumping hours of raw water are available from the registers in the KWA. From that, daily pumping hours have been computed to measure the actual quantity of water pumped into the system for purification by using the actual discharge capacity of each pumps obtained from the KWA. The daily water pumped has been worked out and then all those have been aggregated to that of the years from 1983-84 to 1991-92. The actual monthly quantities of energy consumed by this plant since 1974-75, have been collected from the electricity board and making use of the same, and taking the production for the year 1983-84 as the base, the production has been estimated for the remaining periods. Data prior to 1983-84 are not available with the KWA.

The following quantities have been accounted for the plant loss for backwash and cleaning. The total period of 18 years after commissioning have been divided into three sub-periods. During the first 6 years from 1974-75, 2.5 per cent of the production has been provided for plant loss; during the second 6 years 5 per cent; and the last 6 years 10 per cent has been accounted. The rationale for the second 6 years providing 5 per cent plant loss is that it is possible that the wastage would have occurred during these days due to the wear and tear of the machinery.

The study conducted by M/s. Tata consultants for the rehabilitation of TWSS[2], it is mentioned that there are structural cracks in the central pillar of the second stage clarifier. The inlet well to the clarifier in stage two is leaking and filter beds 3 and 4 of second stage filter plant is leaking. Quantification of the first two items are really impossible and the third is told to be of the order of 2.5 cum/hr and 10 cum/hr respectively. Hence the plant loss is assumed to be of the order of 10 per cent during the last 6 years of our analysis.

3.4. Data on Demand Analysis.

The data for the purpose of demand analysis of the pattern of drinking water was made on the basis of a field survey conducted within the corporation area of Trivandrum. For the purpose of the

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2. Water supply improvements to Trivandrum city region - Interim report on rehabilitation work studies - Tata consulting Engineers, Bombay December (1991) and January (1992).

survey, a suitable schedule has been designed and pretested. Necessary changes had been incorporated in the schedule based on the pretest results. Stratified random sampling was adopted to select the samples for the field investigation to give each group a proportional representation according to the population in each strata. The total number of constructions made within Trivandrum corporation area as on 31st March 1992 was taken as the frame, by using the corporation "T.C" numbers allotted to each construction. Though TWSS extends it's operational area outside the city corporation also, the survey area is limited within the boundaries of Trivandrum corporation as it was difficult to get an appropriate frame for drawing suitable samples for constructions outside city limit. Moreover the majority of the consumers of the TWSS are within the corporation area itself, hence the limit fixed as within corporation area. However, there cannot have much variability even if the survey area is extended beyond city limits.

The entire frame was sub-divided into 8 strata based on the annual rental value of the building and the half yearly municipal tax charged by the corporation in order to get a self weighting sample from each of the categories of income class. The annual rental value can be counted approximately as a measure of the income class to which the particular sample belongs to. Such strata were formed in order to get representation for all types of consumers. Samples have been drawn from all the strata with probability proportionate to population using circular systematic method with a random start. One schedule was canvassed for each of the selected sample, by making personal visits to the concerned corporation number. The samples drawn and surveyed was 555, and wherever no water connection was found, the next construction in the same strata who has water connection has been substituted.

The following table would give an overall picture of the sampling frame and method of selection.

Table 3.1

Sample Survey Frame

Range of Half Yearly tax	Maximum Occur: ance	Percentage Frequency	Interval Selected	Random Start Chosen	No of sample Drawn
0-10	15250	13.75	201	5545	76
10-25	14204	12.81	200	11742	71
25-50	15500	13.97	199	7092	78
50-100	20405	18.40	200	9243	102
100-150	12491	11.26	201	11322	62
150-200	11105	10.01	198	10302	56
Above 250	12008	10.82	200	8300	60
Buildings With ARV=0	9966	8.98	199	8922	50
TOTAL	10929	100.00	555		

ARV - Annual rental value.

The data thus collected from the field have been tabulated and used for making the analysis of demand.

Chapter IV

STATISTICAL COST ANALYSIS

Introduction:

The behaviour of cost function of any firm or industry can be analyzed both in the short run and in the long run. In the short run, the fixed factors like capital, capacity of the plant etc are fixed. Only the variable inputs to the system can change, and thereby within the limitations of the plant capacity only the enterprise will be able to maximise it's production. In the long run, all inputs are variable, more capacity additions can be made or better technology can be imparted that cost saving methods can be deployed.

This chapter on the cost functions makes use of the same for the formulation of the pricing policy. The chapter begins with the specification of cost function, followed by the estimation of cost function for two plants separately and at the aggregate level.

4.1.1 Theory of Cost Function:

A firm utilises a variety of productive services per unit of time to produce a certain flow of output. The relationship between cost and output then depends essentially upon three factors: (1) The production function, (2) The conditions of supply of factors of production to the firm and (3) The optimality conditions. For the specification of the cost functions, the cost minimising behaviour of the firm is as usual.

The cost function from producer equilibrium is given by

$$\text{minimise } C = \sum_{i=1}^{n} w_i X_i \qquad \text{---------------} \quad 4.1$$

subject to $f(X) \geq O$

where $O = f(X)$ is the standard production function

and Xi's are the inputs and Wi's are corresponding prices

The result of 4.1 defines the long run cost function of the firm which is given by

$c = c(W,O)$, w: a vector of 'n' input prices.

In the short run some input in the production function are fixed, and therefore short run cost function becomes

$C = C\ (w,\ O,\ \bar{X}_k)$

where $\bar{X}_k$ is the fixed inputs.

The properties of cost function are:

1. $c(W,O) > 0$ for $W > 0$ and $O > 0$ (non negativity);
2. if $W' \geq W$, then $c(W',O) \geq c(W,O)$ (non decreasing in W);
3. Concave and continuous in W;
4. $c(W,O) = tc(W,O)$, $t > 0$, (positively linearly homogeneous);
5. if $O \geq O'$, then $c(W,O) \geq C(W,O')$ (non decreasing in O); and
6. $c(W,f) = 0$ (no fixed cost).

Our objective is to estimate the short run cost function for water which is dealt with in the next section.

4.1.2 Statistical Cost Estimation: Plant Wise and Aggregate:

For the purpose of this study, the estimation of statistical cost and the analysis of it in the short run alone has been attempted for the simple reason that the plants are given. Some of the earlier studies (Clark and Stevie, 1981) conducted in industrialised nations have broken the cost structure into four or five categories (1) the cost of pumping raw water in the intake from where the raw water is drawn,(2) the cost of purification, (3) the cost of transmitting the treated water through trunk mains, (4) the distribution cost, (5) metering and allied activities and laboratory and other services for examining both raw water and treated water. However, since our purpose of analyzing the cost structure is to ultimately fix the prices, the aggregate of all the above have been followed. Apart from this the availability of data on the dis-aggregated level is also very poor.

In the short run the plants are fixed and the technology is given. The technology of the two plants are different and are of two different vintages. Hence, to analyze the impact of technological difference on cost of production the cost functions of both the plants are analyzed separately. Further, to determine the prices, the analysis was carried out after aggregating them. The distribution system of Trivandrum Water Supply System is not plant wise separable. Nor there be any measure to identify, how much quantity has been supplied to a particular area from each of these plants. Hence, to overcome the difficulties in pricing an aggregate cost function is used.

The cost of production of drinking water has been broadly divided into two: (i) the production cost and (ii) the distribution costs. The former includes the pumping cost of both the raw water as well as treated water till it reaches the storage tanks after treatment along with the cost of treatment incurred, and also the laboratory charges. The latter are those incurred for the distribution and maintenance of distribution network, metering system, small line extensions, expenditure incurred in connection with collection of revenue etc. The cost compiled from the books of accounts of Kerala Water Authority is including the input price effect and the output price effect.

In the short run, the change in the total cost is equal to the change in two components. Specifically:

$$\Delta c = \Delta w + \Delta o \qquad \text{------------ 4.2}$$

Δw : change due to input prices ; Δo : change due to output.

For the calculation of Average cost the cost variation due to output variation alone is needed. This can be calculated if the cost is deflated with an appropriate index of input prices.

This methodology followed earlier by Johnston, (1960) has been used in the present analysis. In order to estimate the relationship between cost output the total variable cost has to be deflated with an appropriate input price index. A weighted average of consumer price index of industrial workers, price of electricity and price of chemicals have been used for this purpose. The weights are derived from the proportionate share of each item in the total cost. The adjusted total variable cost is then related to output of two plants separately and in the aggregate[1] .

The Total variable cost (Tvc) = c = W

$TVC_t = C_t = W_t + P_t + C_t + A_t + C_t + B_t$ ------------- 4.3

where W_t = Wages and Salaries of the employees

P_t = cost of Electricity for production including yard lighting

C_t = cost of Chemicals including transportation charges

A_t = Administrative cost

M_t = Cost for maintenance, repair, and upkeep of building and fixed capital

According to Johnston (1960), "In a firm producing single homogenous product, the production function can be stated as the relationship describing the maximum flow of output per unit of time achievable for any given rate of flow of input services per unit of time". The raw water used for purification as an input or raw material is a free gift of nature and only the capital expenditure incurred for bringing the same to the plant, either through pumping or through gravitational flow for treatment and purification has been considered. Acquisition of raw water involves either tapping a source of water that is adequate in quantity to satisfy present and reasonable future demands on a continuous basis, or to convert an intermittent source into a continuous supply by storing surplus water for use during the periods of low flows. Since good drinking

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1. For details of the data, see chapter III.

water is a must for human existence, opportunity cost is not attributed to the quantities of raw water used. Hence, the cost of raw water is zero except for its cost of pumping and catchment through Dam which are accounted for in the fixed cost.

The average variable cost function, derivative of total production and of output, is estimated using the following regression equation.

$$Avc = \alpha_0 + \alpha_1 O_t + e_t \qquad \text{------------- 4.4}$$

where $Avc = C_t / O_t$,

Where O_t is output measured in million litres per year; C_t is the cost of production of O_t; and e_t standard error term.

`T' has been introduced in order to ascertain whether there is any systematic shift in the cost function during the period. The reason which prompted for a trial of the regression in that direction is the continuous fall in the capacity of the raw water carrying conveyance main.This version of AVC equation 1:

$$Avc1 = \alpha_0 + \alpha_1 O_t + \alpha_2 T + e_t \qquad \text{-------------- 4.5}$$

These equations are estimated below in the following sub-section.

4.1.2 Estimation of Cost Function:

As mentioned earlier, the cost functions are estimated separately and jointly for the two plants.

In Plant I, unlike that of the second plant, the breakages of the system are less or even negligible since the dependence on power for running the plant was very minimal, during the initial years of it's operation in the production process except for the pumping of treated water from the low level sump to the high level tank. It is observed that the breakages in production were generally due to power failures. Since the major part of the system was not using power for carrying raw water to the plant during the initial years of analysis, it is assumed that the production process was continuous. If at all there were some breakages, it would have been recouped through subsequent pumping to the high level tank. Though the boosting of raw water flow takes place in the raw water main by using power even without that, a minimal flow to the treatment plant was assured, through gravity. As years passed, the effective capacity of raw water carrying main got reduced due to excessive formation of tubercles and thereby a very minimal flow alone had taken place through gravitation. In order to cope with the capacity reduction in the raw water main, more of energy oriented methods had been resorted, since the gravitational flow was obstructed consequent on the formation of tubercles[2]. Over years this scenario had led to a total technological shift in the plant which is verified by the empirical analysis.

The detailed methodology of data problem is given in chapter III. The period of analysis is restricted to 1972/73 to 1991/92 purely due to data problems. The total quantity of production was

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[2]. The KWA had installed two more 250 h.p. pump sets in the premises to boost the flow of water to the raw water carrying main besides the 4 90 h.p. pump sets already installed earlier. Certain capacity reduction in the 90 h.p. pumps would have taken place by this time.

estimated from 1972-73 to 1991-92 after permitting a plant wastage of 2.5 per cent[3] of raw water pumped for backwash filter cleaning etc. Further, the leakages in the distribution system has also not been considered in the analysis of production. The final results are reported in Table - 4.1.

Table 4.1

Estimated Cost Function

VARIABLES	PLANT I		PLANT II	
	Eqn. 4.1	Eqn. 4.2	Eqn. 4.1	Eqn. 4.2
Constant	2184639.7 (8.81)*	1279754.7 (5.9)*	52.11 (7.6)*	61.60 (7.7)*
Output	-86.94 (-4.1)*	-53.33 (-3.6)*	0.002 (4.7)*	0.0001 (0.13)
Time	---	42548.96 (7.0)*	---	2.03 (1.9)**
Adj. R Square	0.66	0.87	0.56	0.62
D. W Statistic	1.11	2.37	2.16	2.02
F- Statistic	19.7	67.3	22.5	15.1

Notes: * indicates level of significance at 1 per cent and
** indicates level of significance at 5 per cent.

The estimated equation 4.4 for plant I is significant only if the output is adjusted for seasonality (3 year moving average has been used) Note that the D.W is in the inconclusive region. However, the inclusion of a trend variable without adjusting output for seasonality gave a correctly specified model. This model 4.5 shows

[3]. Studies conducted in this regard show that the plant loss can vary between 2.5 per cent to 5 per cent of raw water pumped. Since plant -1 is found to be of a better capacity utilising one plant loss is taken at it's minimum.

that the average variable cost is increasing during the period. This can be interpreted as the increase in the technical inefficiency in production due to the formation of tubercles in the raw water carrying main. This tubercles formation forces the plant and the system to produce at a decreasing rate resulting in average cost function for plant I. The regression equation estimated for plant II, the shift variable is significant but output is insignificant. This relationship is not valid for plant II as seen from equation 4.5 since only `T' is significant but not output. Moreover the AVC is increasing as imputed in equation 4.4.

The intercept for plant I is observed to be very high as compared to plant II. This can be attributed to the following reasons:

i. Plant I mostly employs the employees of permanent nature and their wage bills are obviously higher than that of the temporary staff.

ii. The Dandapani commission award of 1976-77 constituted by the then Government of Kerala to study the problems of making the temporary employees of the erstwhile Public Health Engineering Department. to permanent has much of it's effect on plant I, since it was the one started earlier and had a large number of employees who had put in a higher years of service. This had paved way for making a large number of temporary workers to permanent employees. The full effect of the implementation of Dandapani commission report has started it's influence on plant I during the onset of 80"s. and

iii. Since the machineries and pumps installed are of old vintage the replacement cost and repairs to such equipments are booked under the maintenance head by the KWA show a high constant in the regression.

The plant wise average cost of production of both plants is estimated in the following way. While the average cost for plant II is the predicted cost evaluated at the capacity output, the average cost of Plant I is estimated in the following way due to technical problems mentioned earlier. Since the average cost is a decreasing function of the capacity output, the average cost for plant I is estimated using the following function.

$$Avc = \alpha_0 + \alpha_1 Q_t + e_t$$

Where Q = actual output/capacity output for plant I, and the estimated equation is:

$$Avc = 354.95 - 280.17\, Q$$
$$(12.09)^{*} \quad (-8.74)^{*}$$

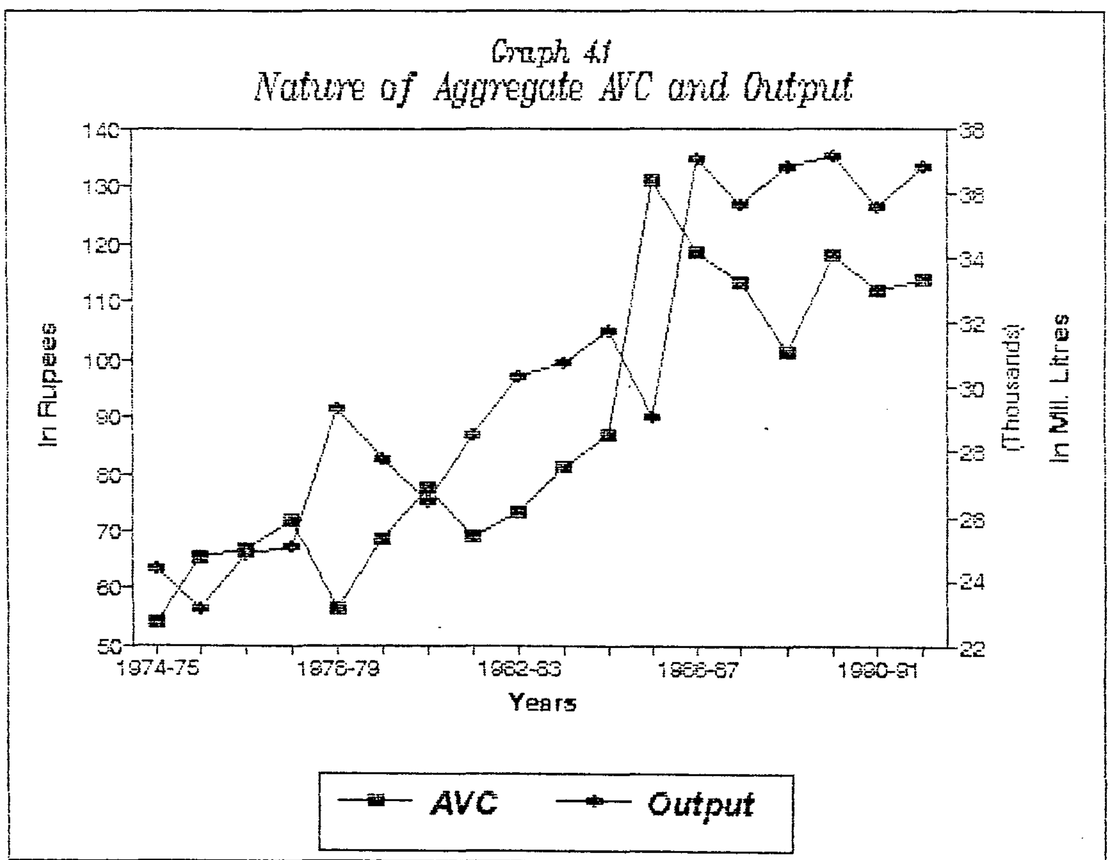
Adj R Square 0.80; D W statistic 1.70; F-statistic 76.41 and N 20;
* significant at 1 per cent level.

The average variable cost of the capacity output is obtained when Q = 1, which works out to be Rs 74.78/ m.l. In the case of plant II the average cost evaluated at the capacity output (26280 m.l.= Rs. 104.67). From the results it is clear that the average variable cost is much higher for Plant II. This cost difference will only increase if the fixed cost component of the plants is added. Therefore the economic way of producing drinking water would have been correcting the first plant for capacity output. Only after reaching its capacity the second plant should have been started.

4.2.3 Estimation of Aggregate Cost Function:

Though plants I and II are operationally separable the outputs of both the plants are distributed through the same distribution line. Hence, aggregate analysis of the costs of both plants I and II have been carried out for making use of it to price the system. Therefore we estimate the aggregate cost function.

The nature of aggregate AVC is given in Graph - 1.



Graph 4.1
Nature of Aggregate AVC and Output

Three functional forms were used for the estimation.

(1) $AVC = \alpha_0 + \alpha_1 O_t + e_t$

(2) $AVC = \beta_0 + \beta_1 O_t + \beta_2 O_t^2 + e_t$

(3) $\log AVC = a + b O_t + e_t$

It is observed that in the combined data on variable cost of the TWSS both linear and quadratic regressions did not show a significant result. The last fitted equation, exponential cost curve is seen better.

$$\text{Log avc} = 3.039 + 0.00004\, O_t$$
$$(11.32) \quad (5.27)$$

Adj. R square 0.61; D W Statistic 1.96; F-statistic 27.73 and N 18.

The exponential cost curve suggest that the AVc is increasing at an increasing rate. This should have been caused in two ways. The cost of production in both the plants are increasing. In plant I, it is due to the under utilisation of capacity and inherent technical problems leading to excessive energy consumption to produce the required possible quantity. In Plant II, the technology itself is such that more and more energy is required to produce more. As mentioned in chapter III the second addition to Plant II, was leaking within the plant itself because of the faulty construction. The high quantity of leakage within plant II itself caused the increase in the cost. All these factors led to the exponential cost, when the variable costs were clubbed together. The technical efficiency was also examined for the aggregate system, by using time as a variable. The results show the following:

$$\text{Log AVC} = 4.479584 - 0.00002\ O_t + 0.0656\ T$$

(10.74) (-1.19) (3.91)

Adj. R-sqare 0.79; D W statistic 1.02; F-statistic 33.87 and N 18

In the above regression though the coefficient of T is significant the value of output is found to be insignificant. We know from the earlier analysis that over years a systematic shift is taking place in technology in Plant I, whereas the same is not found in plant II. However the same is not reflected in the aggregate analysis also. This is because, the capacity of Plant II is double the capacity of plant I. Hence the reason why the shift in technology in plant I is not reflected in the aggregate analysis.

Summary:

Separate cost functions were statistically estimated for plant I and Plant II in order to bring out the effect of technology on cost of production. The evidence shows that plant I, the oldest established during 1933 is still cheaper if produced at capacity output. For the calculation of the prices an aggregate cost function is estimated. While the plant wise short run cost function is linear, the aggregate function turns out to be an exponential function.

Chapter V

SOCIO-ECONOMIC FACTORS INFLUENCING DEMAND FOR WATER

Introduction:

Most of the studies on demand for public utilities have the conventional framework for the analysis. The demand for drinking water is not an exception to this[1]. These studies hold the view that, price determines the level of demand. However, this argument need not hold good in an economy characterised by the state owned or managed public utility systems[2]. In an economy where the state owns water utilities, the consideration of cost aspects are generally ignored, and hence the government meets the expenditure, incurred in providing the services, in the form of subsidies. In such economies the welfare of the people, socio-economic situations etc are given more importance.

The demand for water mainly comes from two broad sectors, namely household sector and non-household sector. The non-household sector includes fire fighting service, schools, hospitals, commercial sector and so on. Studies conducted by Tata consulting Engineers (1992) observed that the major portion, about 84 percent of the demand for water in TWSS comes from households. Hence, an

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1. For example Howe and Linaweaver, 1967; Morgan, 1973; Foster, Henry, Beattie and Brucer, 1981; Griffin, Adrian and Martin, 1981; Griffin, Adrian, Martin and Waohe, 1981; Jones and Morris, 1984 and Nieswiadomy and Molina, 1989.

2. When the public utilities are owned and operated by the state or state owned organisations, the state itself is the decision maker to set the price.

understanding of the factors influencing the demand for water of households would be essential for any pricing policy that incorporates the demand aspects too and the present chapter intends in this regard.

Possibly there are two ways of estimating demand for consumption of water which includes household composition effect. The first method is to incorporate the household composition measured by adult equivalent scales along with the socio-economic variables in the same model that is to say we treat all the variables as exogenous. Another method is to express the consumption function as a multiplicative model of household size and socio-economic variables. Under this assumption the per capita consumption is estimated as a function of socio economic variables[3]. In this chapter the second method is followed.

The framework of the chapter is as follows. Section 1 deals with the estimation of household expenditure effect on the consumption. And the adult equivalent scales are estimated for the first time for drinking water and section 2 analyses the per capita consumption and the socio economic factors influencing them. In section 2 the socio-economic determinants of water demand is analyzed. An attempt is also made to estimate it empirically.

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[3]. e.g. $C = c\ (H,X)$
where C is consumption , H is the household size, and X for the socio-economic variables.
$C/H = g(X)$.

Section I

5.1.1 Adult Equivalent Scale - A Survey:

In the traditional analysis of consumption, the effect of the household size is taken out by constructing adult equivalent scale based on nutritional standards. Equivalent scales purport to measure the relative income required to enable the families of different size to enjoy the same standard of living. An inherent problem of this scale is that it does not consider the changes in the welfare generated by a fixed bundle of goods as family composition changes.

Engel recognised the different needs of children and economies of scale in consumption, by writing 'ei' per equivalent household as a function of total expenditure per equivalent household. Thus, ei/mo = gi(x/m0) where mo (a) is the number of reference households to which household with composition 'a' is equivalent. m_0 is the number of equivalent adults if the reference household is a single adult. With this it can be shown that the budget share is the indicator of welfare X/m0, the budget share being,

$$W_i = e_i/X = m_0 g_i \ (X/m_0)/X = F_i \ (X/m_0)$$

But critics like Muellabuer (1977) argues that Engel theory is restrictive because the increase in equivalent price is the same for each good. The demand relations, utility and cost functions developed subsequent to that of Engel are produced in a tabular form of equations which would provide an idea of the behaviourial implications of the forms of demand relations and the cost functions in respect of some of the main models of household composition effects. In all cases, the parameters 'mi' are functions of household composition 'a'. The equivalent expenditure at constant prices of a household with composition 'a' relative to that of some reference household with composition a0 is

$$C\ (U,P,a)/\ C\ (U,P,a0) \equiv \text{equivalence scale.}$$

A Tabular survey of equivalent scale models.

Demand relations | **Utility and cost Functions**

Engel (1895)

$e_i/m_0 = g_i(X/m_0)$ ---(1) $U=U(q_1/m_0(u),\ q_2/m_0(u), \ldots q_n/m_0(u))$ ..(2)

$X = m_0(u)\ \hat{c}\ (u,P)$ ....(3)

at constant prices and m_0 depends on X as well as on 'a'

Prais Houthakkar (1953,1955)

$e_i/m_i = g_i(X/m_0)$ ...(4) $U = \mathrm{Min}(q_i/m_i\ \alpha_i(u))$ ....(5)

$m_0 = m_0(m_1, m_2 \ldots m_n, X)$ $X = \Sigma\ p_i m_i\ \beta_i(u)$ ....(6)

at constant prices where $\beta_i(u) = g_i\ (X/m_0)$

Barten (1964)

$q_i/m_i = D_i(p_1m_1/X, p_2m_2/X, \ldots p_nm_n/X)$ ....(7)

$U = U(q_1/m_1, q_2/m_2, \ldots q_n/m_n)$ .....(8)

$X = C(U, p_1m_1, p_2m_2, \ldots p_nm_n)$ ......(9)

Gorman (1975)

$\hat{q}_i/m_i = \hat{D}_i(p_1m_1/\hat{X},\ p_2m_2/\hat{X} \ldots p_nm_n/\hat{X})$ ....(10)

Where $\hat{q}_i = q_i - \alpha_i(a)$ $U = U\ (\hat{q}_1/m_1, \hat{q}_2/m_2 \ldots \hat{q}_n/m_n)$ ...(11)

and $\hat{X} = X - \Sigma P_i X_i(a)$ $X = \Sigma P_i X_i(a) + \hat{C}(u, p_1m_1, p_2m_2 \ldots p_nm_n)$ (12)

Muellbauer (1975)

$$Q_i = \sum_{j=1}^{k} \delta c_j/\delta p_i\ (U, \delta_{j1}p_1, \delta_{j2}p_2, \ldots \delta_{jn}p_n) \quad \text{..................(13)}$$

No explicit form of the direct utility function where U is an implicit function of X, the p_i's and the δ_{ji}'s.

$$X = \sum_{j=i}^{k} (c_j(U,\ \delta_{j1}p_1,\ \delta_{j2}p_2, \ldots \delta_{jn}p_n) \quad \text{.......(14)}$$

Source: Muellbauer, 1977: 463

According to Muellbauer (1977), the Prais Houthakkar model generalises the Engel model by allowing different price equivalent effects for each commodity and he argues that it is not free from the identification problem. He further argues that the estimates tried on Barten model also suffers from the problem of identification. Also it has been shown that the Prais Houthakker model can in fact be regarded as a special case of (14) if mi(a) is linear and additive in the elements of a.

In most of the above cases, the classification of children in one group and adults in another group influences each other in the consumption pattern. To quote Gronau (1988 and 1991), "a change in children's need may affect their parents consumption .... one should be able to trace changes in ß (differences in children's needs) by observing the changes in consumption pattern with children's age, but since the effect depends not only on the change in consumption technology parameters but also on the substitution elasticity. One cannot separate the two without prior information on the substitution elasticity of parent's consumption. A decline in parents consumption as children grow is constituent with an increase ß, if X^{β} is price elastic". It may be true in respect of certain consumer goods, however, becomes incorrect with respect to drinking water since it is price inelastic at least to a minimal point and substitution is not possible.

In the Prais Houthekker and Price model of estimating adult equivalents in consumer behaviour and expenditures per adult equivalent are expressed as a function of income per adult equivalent. The model is of the following form

$$E/\Sigma c_j n_j = aj\ (Y / \Sigma d_j n_j)^b$$

Where E is the expenditure on a particular commodity per household, Y is the income per household nj is the number of persons in a particular age and sex group per household, cj is the adult equivalent scale for a particular commodity, aj is the adult equivalent scale for income, a is the regression constant and b is the income elasticity. In this approach a specific type of person is characterised by the set of weights cj for each commodity, but the income of the household is divided by a measure using weights dj which represent a general scale.

The demand for water of children would also increase as they grow up until they reach adulthood wherein it may saturate. And also, it shall remain inelastic to prices for a minimal demand. Deaton, Castillo and Thomas (1989) argue that the consumption of adults may be affected as more and more members are added to the family in the case of food products. This can be true in the case of some goods depending on the level of income of household and the nature of commodity, which need not be true in case of drinking water. Any reduction in the quantities demanded as a result of addition of more children can, if at all take place[4], only after surpassing the minimal requirement and thus, cannot influence the consumption of water per adult as water is a basic necessity for survival. In light of this, it is very difficult to make use of the adult equivalent scales used for food items. Hence, the present study

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4 . If one argue that the addition of children , keeping the income of the family constant may force the parents to restrict their children to consume less quantity, or the parents themselves make a self imposed restriction by themselves.

attempt to construct an adult equivalent scale from a primary survey data.

5.1.2 Estimation of Adult Equivalent Scales for Water:

In the Prais Houthakkaer and price approach, household members are grouped according to their age, sex, etc., so as to have a step-wise discrete specific scales, ignoring socio economic characteristics of the households. However, Buse and Salthe (1978: 460-461) argue that socio-economic characteristics of household are also important factors influencing household expenditure variation. As the scales for a particular individual is being viewed as constant over a period which take on new values at age thresholds in the Prais Houthekkaer approach, it becomes quite restrictive for the purpose of present analysis. Although some studies (Deaton, Castillo and Thomas 1989; Gronau, 1991) consider intra family composition on non-food items like clothing, education, etc. based on adult equivalent scales, it seems to be doubtful that it can form a basis to the present analysis.

The adult equivalent scales for estimating demand have been worked out from the monthly consumption data of the 555 households surveyed. The data have been classified according to their sex, age, etc. The data on children have been further classified into two, namely, those below five years and those between 5 to 15 years. The classification of children into two groups is based on the following observations. Children of below 5 years of age normally faces some restriction on the use of water as imposed by the mother or other adult members, besides the fact that their water requirement is less. And, the children of the age group between 5 to 15 years enjoy relatively more freedom in using water, in addition to their more water requirements. It is also assumed that the children will be completely free from the restrictions imposed by parents while reaching 15th year of age. It is with these assumptions that the model is formulated.

To understand adult equivalent scales, one has to understand the intra family allocation of this commodity. The adult equivalent scales are derived from the survey data, basically following the Prais - Houthekker approach, especially because of non substitutability of the commodity. Deaton and Muellabuer argue that the Prais-Houthekker model is consistent with the theory of consumer choice only in the case where the utility function permits no substitution between goods (Deaton and Muellabeur, 1980). As water is non-substitutable in nature, the welfare implications involved in the intra family allocation have not been brought to this analysis. Moreover the addition of children to the family does not affect the consumption of water by parents and vis-a-vis it does not affect the individual welfare also.

A simple method is used to measure the adult equivalent scale which is discussed below. The incremental average consumption of the household with different household size gives the average consumption of adult male, adult female and children belonging to different age groups. The actual average consumption is then used for calculating the adult equivalent scale, which is discussed below. The average quantities of water consumed by households has been defined as follows:

$\alpha 1q$ = The average water consumption of households with one adult male and one adult female;

$\alpha 2q$ = The average water consumption of households with $\alpha 1q$ + 1 child of age below 5 years;

$\alpha 3q$ = The average water consumption of households with $\alpha 2q$ + 1 child of age 5 to 15;

$\alpha 4q$ = The average water consumption of households with $\alpha 1q$ + 1 adult male;

$\alpha 5q$ = The average water consumption of households with $\alpha 1q$ + 1 adult female;

The adult equivalent of scale of each category from the above definitions are:

Average consumption of adult female $= \alpha 5q - \alpha 1q$

Average consumption of an adult male $= \alpha 4q - \alpha 1q$

Average consumption of children below 5 years $= \alpha 2q - \alpha 1q$

Average consumption of children between 5 and 15 years$=\alpha 3q-\alpha 2q$

The adult equivalent scales of males and children are the average consumption calculated, based on the data, is given below:

$F = 1$

$M = (\alpha 4q - \alpha 1q)/(\alpha 5q - \alpha 1q)$

$C_{0-5} = (\alpha 2q - \alpha 1q)/(\alpha 5q - \alpha 1q)$

$C_{5-15} = (\alpha 3q - \alpha 2q)/(\alpha 5q - \alpha 1q)$

where F, M, C_{0-5} , C_{5-15} are female, male, children below 5 years of age and children of 5 to 15 years of age respectively. The average quantities of consumption across households by different size are given below.

Table - 5.1

Household Average Monthly Consumption by Sex and Age

Household Size	Average consumption Kilolitre / Month
1 Male and 1 Female	15.79
1 Male, 1 Female and 1 Child < 5 years.	16.13
1 Male,1 Female,1 Child < 5 years and 1 Child 5 to 15	16.79
2 Male and 1 Female	18.53
1 Male and 2 female	21.58

Source: Sample survey

The equivalent scale is constructed in the following way. Average consumption, the consumption of adult female is taken as unity. The consumptions of all other categories has been defined as the proportion of female consumption. Thus the adult equivalent scale for water consumption : female equal to 1. Then, M = 0.47, C_{0-5} = 0.06 and C_{5-15} = 0.11 respectively. The household size adjusted for consumption is given by:

$$HA = \sum_{i=1}^{k} (F * aki) + \sum_{i=1}^{l} (C_{0-5} * bki) + \sum_{i=1}^{m} (C_{5-15} * cki) + \sum_{i=1}^{n} (M * dki)$$

Where

HA = Adult equivalent scale of family;
aki = No. of adult female members in the family;
aki = No. of children below 5 years of age in the family;

cki = No. of children in the age group 5 to 15; and.

dki = No. of adult male members in the family.

As mentioned earlier, the water requirements of the female members are much higher than that of the male counterparts. This phenomena is exactly contrary to all the earlier observations on adult equivalent scales generated for food articles (Amsterdam scale). The nutritional requirements of female are lesser, when compared to males whereas it is exactly opposite with respect of water owing to the cultural practices and the socio economic and behaviourial patterns that prevail in the Kerala context. This is clearly explicit from the following Table 5.2.

Table - 5.2

Comparison of Adult equivalent Scales

Sex and Age Group	Adult Equivalent Scale for Water	Amsterdam Scale
(1)	(2)	(3)
Child < 5 years	0.06	-
Child 5-15 years	0.11	-
Male > 15 years	0.47	-
Male < 14 years	-	0.52
Male 14 - 17 Years	-	0.98
Male ≥ 18 years	-	1.00
Female <14 years	-	0.52
Female 14-17 years	-	0.90
Female > 18 years	-	0.90
Female > 15 years.	1.00	-

Source : 1. Deaton and Muellbauer, 1980:193 for Column (3) and
2. Table 5.1

The consumption of one unit, then requires 0.5 for men, for child 5-15 years 11 percent and 0.06 for child below five years. This scale is used for adjusting for household composition effect on consumption by taking per capita consumption.

From the above, the per capita consumption of each household has been derived by using the following equation.

$$Pc = Tc/HA$$

Where Pc is the per capita monthly average consumption of the household and Tc is the total monthly consumption of water within the household.

The above per capita monthly average consumption of the households has been related to their socio-economic characteristics in the subsequent analysis. In addition to this, an attempt has also been made to examine the influence of the socio-economic characteristics of households on the average consumption. The socio-economic determinants of per capita consumption are examined below.

5.3.1. Survey Results:

For the purposes of analysis, total number of household are classified into three different categories according to the type of structure such as pucca, semi pucca and katcha[5]. The analysis of the data exhibits that as the general education of the household

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[5]. The classification of the construction of dwelling unit and the type of it has been in line with the National sample survey (NSSO) classification. Houses with concrete or tiled roof, wall built with burned bricks and plastered with cement mortar, and floor made of cement or mosaic or tiles or such other materials have been classified as pucca. Semi pucca houses are those with wall constructed out of burned bricks and floor out of cement or such other pucca materials but the roof are thatched. Essentially what is meant by semi pucca is that such constructions generally have the characteristics of both pucca and katcha. Houses with mud walls, walls made out of bamboo, reed etc or with lesser quality of materials and thatched roof are classified as katcha.

members in general and housewife in particular, increases the average quantity of water consumed also increases (see Table 5.3 5.4). It may be due to the fact that the more educated are much aware of the need for cleanliness and hygiene. The Tables 5.3 and 5.4 also depicts a picture that those who dwell in Pucca and Semi pucca constructions do have the average consumption much higher than that of those who stay in Katcha houses, which may be attributed to income effect of the families and the level of education and social status they enjoy.

Table - 5.3

Average Per Capita Consumption by level of Education

APCPH / MONTH

Education	Pucca	Semi Pucca	Katcha	All Household
Illiterate	_	_	7.7100	7.7100
Literate below primary	3.4350	3.1350	_	3.2850
Primary	6.1944	5.5015	4.1200	5.5288
SSLC and above	6.9302	5.8248	4.9163	6.2685
Graduate and above	8.6603	6.7384	4.7080	8.1021
Professional graduate and above	10.1392	8.7400	_	10.0393
Diploma holders	8.3280	6.9967	_	8.0208
Others	16.0033	_	_	16.0033

Note: APCPH is Average Per capita Consumption per Household
Source: Same as Table 5.1

Table - 5.4

Average Per Capita Consumption and Housewife's Education

Education of Housewife	Pucca	Semi Pucca	Katcha	All Household
Illiterate	8.2137	7.5554	4.9500	2.8104
Literate below primary	7.4800	4.9922	3.3733	5.7445
Primary	5.8934	5.3507	3.5750	5.3411
SSLC and above	8.0214	6.4897	6.0688	7.4569
Graduate and above	9.8026	7.2062	4.8200	9.4152
Professional graduate & Above	10.4760	_	_	10.4760
Diploma Holders	9.0100	_	_	9.0100

Notes and Source : Same as Table 5.3

Table - 5.5

Average Per Capita Consumption by Number of Taps

No of Taps	Pucca	Semi Pucca	Katcha	All Household
1	5.8569	5.2776	4 .5177	5.2320
2	6.6021	6.2463	4 .4638	6.2380
3	7.2765	5.9543	_	6.9164
4	7.5121	7.2657	_	7.4598
5	10.3217	7.0700	5 .4900	10.0300
6	8.3913	7.6700	_	8.3463
7	9.8872	_	_	9.8872
8	7.7619	_	_	7.7619
9and more	11.9568	_	_	11.9568

Notes and Source: Same as Table 5.3

From Table 5.5, it becomes clear that the mean consumption varies and increases according to the facilities they enjoy, when the number of taps in the household has been considered as a proxy for facilities. The average consumption increases from 4.52 Kl/month in respect of a family with one tap to 11.95 Kl/month in the case of families with taps more than or equal to 9.

Table 5.6, shows that the households connected with flush will have water requirement higher than that of households without flush. Then, the water requirements would necessarily depend on the capacity of the flush that are fitted, as different varieties with different water holding capacities are available. The flush may be considered as the indications as the propensity to pay as the income level of such households would be higher than other categories in general. An abnormally high per capita average monthly consumption is noticed in the case of households of semi pucca category connected with flush, which could be caused probably due to the fact that such households may be newly constructed. These may be originally envisaged for pucca variety because of certain unavoidable reasons they should have left with in between categorising them as semi pucca.

Table - 5.6

Average Per Capita Consumption by Type of Latrine

Type of Latrine	Pucca	Semi Pucca	Katcha	All Household
Households Connected with Flush type Latrines	9.7389	11.5457	-	9.8498
Households Not connected with flush type latrines	7.5062	5.9322	4.777	6.6865

Notes and Source : Same as Table 5.3

Table - 5.7

Average Per Capita Consumption by Type of Garden

Type of Garden	Pucca	Semi Pucca	Katcha	All Households
No Garden	7.8765	6.2062	4.7775	6.2350
Garden with Lawn	10.9365	_	_	10.9365
Garden without Lawn	9.5203	6.2600	_	9.3227

Notes and Source : Same as Table 5.3

Although the frequencies of households with garden are considerably low, (Table 5.7), it reveals that those with well maintained garden use more water. It indirectly indicates the level of income of the household. Only among pucca households use of more water for sprinkling is seen. In the case of semi pucca households, the garden without lawn, using less quantity of water as compared to pucca households, not only show the conscious level of maintenance by the pucca households but also signify essentially the level of income at which the household belongs. Thus, essentially, the Average per capita consumption per household (APCPH) of water in the households of three different categories, not only signify the level of maintenance but also the capability of the household to pay. It may be because of the low capacity to pay that garden, though present, are neglected by the semi pucca households. Although the number of observations having garden are quite less, it is a relevant measure to classify the group of households in the higher income bracket. It may be hypothesised that a well maintained garden leads to high APCPH of water.

Tables 5.8 and 5.9 show the impact of cooking habits and cloth washing on APCPH. A systematic relationship is discernible only among pucca households. The random variations in the usage of water in semi pucca and katcha households, as seen in Tables 5.8 and 5.9, may be because of comparatively low earning employment pattern. And, that they may be having occupations manual labour in nature which increases the water requirements for washing clothes, irrespective of the periodicity at which the washing takes place.

Table - 5.8

Frequency of Cooking and Per Capita Consumption

No of Times Cooking	Pucca	Semi Pucca	Katcha	All Households
1	7.8829	6.1290	4.1256	6.9923
2	8.3541	6.0133	6.4233	7.6086
3	8.6276	5.8929	4.3791	7.4949

Note and Source: Same as Table 5.3

Table - 5.9

Frequency of Clothes Washing and Average Per capita Consumption per House holds

Frequency of Washing Clothes	Pucca	Semi Pucca	Katcha	ALL Households
Daily Wash	8.5025	6.3147	4.2792	7.5539
Once in two days	8.1158	6.4300	7.5375	7.7343
Once in three days	7.2686	7.5017	4.4450	7.1221
Weekly	7.1657	4.8983	7.3133	6.7270

Note and Source: Same as Table 5.3

Table - 5.10

Total Floor area of the House and Average per capita Consumption.

Floor area of the dwelling	Pucca	Semi Pucca	Katcha	All Households
Less than 500 sq.feet	7.2811	5.3675	4.6936	5.4145
500 - 750 sq.feet	6.5186	6.3613	5.4563	602773
750 - 1000 sq.feet	7.4615	6.0888	4.1800	6.9276
1000 - 1500 sq.feet	7.7986	5.7129	_	7.6416
more than sq.feet	11.2529	10.0233	_	11.1459

Note and Source: Same as Table 5.3

Table - 5.11

Number of Bath Rooms and Average Per Capita Consumption

No of Bath Rooms	Pucca	Semi Pucca	Katcha	All Households
1	6.7637	5.8153	4.8690	6.1426
2	8.2227	7.6100	3.8750	8.1095
3	11.2284	8.6000	_	11.1592
4 or more	11.4086	_	_	11.4086

Note and Source: Same as Table 5.3

Table - 5.12

Frequency of House Cleaning and Average Per capita Consumption.

Frequency of House Cleaning	Pucca	Semi Pucca	Katcha	All Households
Daily	8.7937	5.1771	1.9000	7.9461
Once in two days	11.1029	6.0833	2.3600	9.4962
Once in three days	8.7286	6.6223	4.8550	7.9302
Weekly	7.6377	6.0550	5.2100	7.0105
Others	7.7550	5.7329	3.5700	7.0521
No cleaning	8.2770	7.2208	4.9761	4.2949

Note and Source: Same as Table 5.3

Table 5.10 gives the picture that in general, for every increase in floor area of the household the average consumption of water also increases. Similar is the case with the increase in the number of bath rooms. The increase in facilities like number of bath rooms signify the level of living and income of the household, and hence for every increase in facility there should necessarily be an increase in consumption also. As regards Table 5.12, the frequency of house cleaning and the average per capita consumption, the frequency of the activity influences the average consumption, in a systematic manner only in the case of pucca households. The influence of frequency is not much in the other two categories because of the type of construction. The survey data also reveals that the water demand for animal consumption within the city is quite less. This may perhaps be due to the negligible number of households do possess animals in the city area.

5.3.2. Statistical Evaluation of the Consumption Function:

From the above Tables 5.3 to 5.12, it may be seen that the per capita consumption is influenced by general educational status of the household represented by the highest level of formal education obtained by the member of the household, the education of the housewife, the floor area, number of taps and bath rooms, type of flushing system and garden. This is represented by the model given below.

$$P_i = f(M_e, H_e, T_p, G_n, F_g, F_a, B_r, H_c, C_w, IC) \qquad ---(5.1)$$

Where

P_i = Average per capita consumption

M_e= Highest education obtained by the member of the household.

H_e =The educational status of housewife

T_p = Total number of taps

G_n = Type of garden in the household

F_g = Type of flushing system

F_a = Floor area of the dwelling unit

B_r = No. of bath rooms they do have

H_c = Frequency of house cleaning

C_w = Frequency of cloth wash

Ic = Index of household durable the household processes

From the above analysis the effect of socio-economic variables on average per capita consumption is postulated as below.

$\delta f/\delta me : > 0$

$\delta f/\delta He : > 0$

$\delta f/\delta Tp : > 0$

$\delta f/\delta Gn : > 0$

$\delta f/\delta Fs : < 0$

$\delta f/\delta Fa : > 0$

$\delta f/\delta Br : > 0$

$\delta f/\delta Hc : < 0$

$\delta f/\delta Cw : < 0$

$\delta f/\delta Ic : > 0$

The index of household durable was constructed by making use of the average resale value of the durable such as washing machine, floor cleaners, vehicles, cooking and washing equipments, etc and then making a weighted index according to the average resale value it can fetch.

In order to ascertain how far the above variables influence systematically the average per capita consumption, following regression was tried based on equation 5.1.

$$P_i = \alpha 0 + \alpha 1M_e + \alpha 2H_e + \alpha 3T_p + \alpha 4G_1 + \alpha 5G_2 + \alpha 6F_g + \alpha 7F_a + \alpha 8B_r + \alpha 9H_c + \alpha 10C_w + \alpha 11S_e + \alpha 12Ic + u \qquad \text{--------(5.2)}$$

Where all the variables except for G_1 and G_2 are the same as that of equation 1. In the case of Garden 'G_n' dummy variables have been used. The dummies are

G_1 = Garden with lawn is 1

0 otherwise

G_2 = Garden without lawn is 1

0 otherwise

Thus $PC = \sum_{i=1}^{11} \alpha_i X_i$

Some of the independent variables have strong multicollinearity. It is suspected that this multicollinearity between variables would affect the regression results strongly. To determine the degree of association between independent variables, a correlation matrix as shown in Appendix - 5.1 was obtained. The correlations between the independent variables necessitated the dropping of some of the variables already selected, thus restricting the model originally selected.

A high degree of association is observed between number of bath rooms, floor area, number of taps, presence of flush, and level of education. Since the association between flush and number of bath rooms is found to be quite high (significant at 0.001 level) an index of flush per bath room (FBR) has been constructed to capture the influence of these two variables in the regression, thus eliminating the problem of multicollinearity caused by the association between them.

$$FBR = Fg/Br * 1000$$

In order to capture the effect of number of taps and floor area another index of taps per unit floor area has been constructed.

$$TFR = Tp/Fa * 1000$$

These new variables could capture the impact of the four independent variables and also minimise the problem of multicollinearity.

The following modified regression has been fitted in order to capture almost all independent variables we have defined earlier.

$$P_i = \alpha_0 + \alpha_1 M_e + \alpha_2 F_a + \alpha_3 Ic + \alpha_4 FBR + \alpha_5 TFR + \alpha_6 G_1 + \alpha_7 G_2 + \alpha_8 H_c + \alpha_9 C_w + U \qquad \text{---------}(5.3)$$

The results of the regression analysis using these modified variables are given in Table - 5.13.

The highest educational status of members of the household, the total floor area of dwelling unit and the number of taps in the household influences positively the per capita consumption. With education, the awareness for cleanliness and health also increases. Similarly, the larger the floor area, larger area needs to be cleaned and hence higher the consumption of water and such households which will be able to pay for water charges and hence could consume more. The case with number of taps too is not much different. In fact more the floor area in the dwelling unit, it is likely that more number of taps and more consumption. The index of durable also affects the per capita consumption positively. Washing Machines, geysers, Dish washers, etc. do influence the pattern and it implicitly indicates the standard of living of the household in a developing country. Hence those who can afford to have such modern equipments will obviously be having the capability to pay.

Table 5.13

Regression Estimates of Per Capita Consumption

Name of variable	coefficient	T - Stat	ß - Value
Constant	0.23487	0.502	-
Education (Me)	0.96473	4.971 *	0.28595
Floor area (Fa)	0.00171	5.260 *	0.23938
Index of Tap/Floor(TFR)	0.19968	2.555 *	0.10552
Frequency of - House cleaning (Hc)	-0.16413	- 1.641 **	0.06468
Index of durable (Ic)	2.73178	1.797 **	0.10341
Flush Bath room index (FBR)	0.00100	1.216***	0.04474
Garden with lawn (G1)	0.66401	0.753	0.02780
Garden without lawn (G2)	0.67615	0.945	0.03359
Clothes washing (Cw)	-0.02506	- 0.131	0.00491
R square	0.36		
Adj R Square	0.35		
F statistic	34.58781		
Number of observation	555		

Note: * significant at 1% level; ** significant at 10% level; and, *** significant at 25% level

Source: Same as Table 5.1

Secondly such families can be expected to be more aware of the need for hygiene and this could increase water consumption. Effort has been made to capture the impact of vacuum cleaners on the level of consumption, it being a water saving device, but since the number of observations are quite less a valid conclusion could not be reached. The type of vehicle could also be postulated to have a positive influence on the requirement of water which varies for different vehicles. The washing requirements of a four wheeler is definitely higher than that of a two wheeler. However such effects could not be examined for want of sufficient observations.

The flush bathroom index is significant only at 22 per cent but it shows a positive impact as expected, that is if flush bathroom increases the consumption of water also will be high. Only about a little over 20 per cent of the samples do have flushing system and that too predominantly in pucca constructions hence there is the possibility that it may bias the results to some extent.

The frequency at which floor washing takes place gives the expected results. Higher the interval at which the washing of floors take place comparatively lesser quantities of water will be used than doing the same daily or once in two days. Hence the interval at which the washing of floor takes place do influence the consumption. Interestingly about 40 per cent of the households wash their house only weekly which may be due to the predominant occupation pattern in the sample area, mainly white collar jobs who could get time only on a weekly off. The influence of garden with lawn and garden without lawn is not much, since only 4.1 per cent of the sample households do have garden with lawn and 5.9 per cent have garden without lawn. The peculiar climatic situation also influences the demand for sprinkling, so as to make it's effect negligible. Also an analysis of the frequency of washing clothes is made and its impact is found to be negligible, possibly because the volume of clothes washed may remain the same regardless of frequency. The unexplained variation in the fit is quite minimal (0.23) and the degree of association between the per capita average consumption and independent variables are quite good (0.35 per cent).

When separate regressions of pucca, semi pucca and katcha were tried, one interesting observation that could be found in the split regressions is that in katcha households the washing of clothes do influence the water consumption significantly, which is essentially due to the occupation pattern in those households.

Among the ß coefficients reported in Table 5.13 the level of education, total floor area, the number of taps and the index of consumer durable that household possess contributed to the elasticity of per capita consumption, of which education and floor area leads followed by number of taps and index of durable. The average per-capita consumption of those households with professional qualifications is found to be the highest among the categories of consumers according to educational qualification. This phenomena is due to the increased income structure, employment and higher earnings comparatively of the occupants of these households.

The type of structure, whether it is pucca, semi pucca or Katcha has not been included as one of the variables in the regression as the effect has already been captured by other variables like floor area, number of taps, type of education etc. which too have been tried to sort out. The impact of number of bath rooms has already been taken care of in the index of flush to bath rooms .

The above analysis depicts a picture that it is the level of income or per-capita income that influences water consumption, in the case of residential water demand which is analogous to the findings of

Schneider and Whitlatch (1991). However, the attempt made has a different approach to measure the problem as it is very difficult to make a direct measurement of the per capita income of the households.

<u>Limitations of the study:</u>

The probable limitations that one could observe in this study would be that the seasonal variations in the average per capita consumption which is very much related to rainfall summer days etc has not been considered. The role of climatological variations and per capita average consumption is omitted as it is extremely difficult to measure it. The consumption data that are available with the water authority is found to be incorrect as there are a lot of not working meters in the field, which the officials themselves do admit. Moreover the pattern of observation of readings at present is quite inoccuous that they make the readings only twice in a year which is quite inadequate for our seasonal analysis for which at least the quarterly meter readings are to be observed. The above constraints on data has not permitted to make an effort on the direction of the measurement of price elasticity of demand. The water tariff itself was increased only recently after a span of more than two decades, the effect of the increase in price over the average per capita consumption could not be explored in the desired manner. The factors like evapotranspiration, leakages in the system etc have not been considered, the data on such variables are not available, although one or two such studies have been conducted so far.

The influence of non domestic demand on the supply of water, the demand by schools, government offices, industrial demand etc have not been taken into account since adequate secondary data are not available with the water authority. If at all a sample survey is extended to these institutions, it would require larger conceptualisation of the problem, and with the large number of non working meters it is impossible for the water authority also to extend their help.

Summary

In this chapter, the socio-economic factors and the household composition on water demand have been examined using a sample survey of 555 consumers. The effect of household size on consumption is examined first by constructing an adult equivalent scale. The results show that the equivalent scale has unity for adult female, 0.47 for adult male, 0.11 for child between the age of 5 and 15, and 0.06 for a child below the age of 5. The socio-economic factors affecting the water demand after eliminating the household effect is then examined using multiple regression analysis. The regression results show that education, floor area, no of taps per floor area, frequency of house cleaning, consumer durable and numbers of flush bath room influence the per capita consumption of water.

APPENDIX 5.1

CORRELATION MATRIX OF SOICO-ECONOMIC VARIABLES

Correlations:	DURABLES	Education	Housewife's Education	Type of Structure	Floor Area	No. of Taps
DURABLES	1.0000	.7599**	.6201**	.4850**	.5435**	.4842**
Education	.7599**	1.0000	.7225**	.3193**	.5680**	.5281**
House wife's Education.	.6201**	.7225**	1.0000	.2242**	.4859**	.4448**
Type of Structure	.4850**	.3193**	.2242**	1.0000	.0155	-.0889
Floor Area	.5435**	.5680**	.4859**	.0155	1.0000	.6434**
No. of Taps	.4842**	.5281**	.4448**	-.0889	.6434**	1.0000
Bath rooms	.5498**	.5829**	.4729**	.0095	.7024**	.8296**
Flush connect.	.2746**	.3493**	.3055**	-.1497**	.4055**	.5963**
Garden Type	.1578**	.1961**	.1652**	-.1009*	.2692**	.3335**
DUM1	.1604**	.1708**	.1418**	-.0785	.3069**	.4337**
DUM2	.1004*	.1368**	.1161*	-.0743	.1573**	.1723**
Cloth Washing.	.3902**	.3539**	.3478**	.2341**	.2097**	.1598**
House clean	.4565**	.4446**	.3858**	.2130**	.2319**	.2223**
PERCAPIT	.4860**	.5395**	.4418**	.1057*	.4863**	.4954**

Correlations:	Bathroom	Flush Connect	Garden Type	DUM1	DUM2	Cloth wash
DURABLES	.5498**	.2746**	.1578**	.1604**	.1004*	.3902**
Education	.5829**	.3493**	.1961**	.1708**	.1368**	.3539**
Housewife's Education	.4729**	.3055**	.1652**	.1418**	.1161*	.3478**
Type of Structure	.0095	-.1497**	-.1009*	-.0785	-.0743	.2341**
Floor area	.7024**	.4055**	.2692**	.3069**	.1573**	.2097**
No. of Taps	.8296**	.5963**	.3335**	.4337**	.1723**	.1598**
Bath rooms	1.0000	.5756**	.3117**	.3784**	.1724**	.1805**
Flush Connect.	.5756**	1.0000	.2632**	.2971**	.1551**	.0977
Garden Type	.3117**	.2632**	1.0000	.3467**	.9186**	.0543
DUM1	.3784**	.2971**	.3467**	1.0000	-.0523	-.0131
DUM2	.1724**	.1551**	.9186**	-.0523	1.0000	.0633
Clothes wash	.1805**	.0977	.0543	-.0131	.0633	1.0000
House clean	.2338**	.0690	.0200	.0090	.0175	.2553**
PERCAPIT	.5557**	.3457**	.2091**	.1888**	.1431**	.2017**

Correlations:	House clean	PERCAPIT
DURABLES	.4565**	.4860**
Education	.4446**	.5395**
House wife's Education	.3858**	.4418**
Type of Structure	.2130**	.1057*
Floor area	.2319**	.4863**
No. of Taps	.2223**	.4954**
Bath rooms	.2338**	.5557**
Flush connect.	.0690	.3457**
Garden Type	.0200	.2091**
DUM1	.0090	.1888**
DUM2	.0175	.1431**
Clothes wash	.2553**	.2017**
House clean	1.0000	.1921**
PERCAPIT	.1921**	1.0000

Chapter VI

ALTERNATIVE MODELS OF RATE STRUCTURE

Introduction:

Pricing of public utilities should include both elements of cost and demand conditions. Hardly any such study exists on the rate structure of water utilities in India. This chapter makes an attempt in this direction. The theoretical basis of the model is given briefly. Hanke (1972) argues that for water to be used in an economically efficient manner, consumers should be charged a price equal to the short run marginal opportunity cost. If water is sold at prices that exceed marginal opportunity costs, buyers would purchase less than the optimum quantity. (Hanke;1972). This policy of pricing can be applied only in a situation where the capability of all the people to pay, commensurate with their needs. While Brown and Sibley (1986) put forth that given a regulated firm that must break even, and which serves 'm' markets, the efficient set of prices p1, p2, ..., pm is that set which maximizes, total surplus subject to the constraint that the firm earns zero profit. They argue that in certain regulated markets like electricity, water or natural gas, it is extremely unlikely that a customer will drop out of market however high the tariff is. The thrust of their argument is equity in welfare and efficiency in the provision of services, however ignoring the capability of the consumers to pay. The manual of American water works association (AWWA; 1954) and the United Nations recommend that every water works should receive a gross revenue in an amount that will suffice to provide adequate service for maintenance, development and perpetuation of the system. This would imply that total revenue should be equal to total cost. This concept is nothing but the break even condition familiar in the business economics.

In countries where such public utilities are owned by the state the provision of basic amenities becomes primarily its responsibility. Thus it becomes the responsibility of the state to look into the welfare of the people and to provide the services to the poorest of the poor at a lesser price, considering the capability to pay. Simultaneously the system should run at it's break even. This chapter develops a model of pricing which satisfies the above condition.

The outline of the chapter is as follows. Section - 1 deals with the methodology of recovering the fixed cost including inflation from the consumers using a dynamic model. The second is concerned with the pricing of water based on the average variable cost. Two models are developed; one with the type of construction as a proxy to income as the basis of pricing and the other the quantities of consumption. Both the models include a cross subsidy between consumers. Section 3 gives summary and limitations of the model with suggestions for future research.

Section I

6.1.1. Break even cost:

The break even cost condition is given by

Total revenue (TR) = Total cost (TC)

TR = TC or P = Ac.

But AC = AFC + AVC

Our objective in this analysis is to develop a two part pricing structure that recovers both the AFC and AVC. The average fixed cost is examined first.

6.1.2. Recovery of Fixed Cost : A Dynamic Model:

Fixed cost of water supply systems are the plant and machinery, the water conveyance mains and the distribution network. If the life period of the above fixed capital is known, then one could device a formula for its recovery. Generally they are having a longer life expectancy. One can use the project evaluation methods to recover the fixed cost, however this method is not considered in the present case due to the following reasons.

(i). As the plant life is expected to undergo a longer period (fifty years generally) it may be very difficult to predict what would probably be the shadow prices that are to be assigned to these machinery and equipments so as to replace it after fifty years;

(ii). It is extremely difficult to predict at this juncture what sort of technological innovations that can take place within this fairly long span of time. The technological innovations also influences the cost and hence it is undesirable to approach the problem using project evaluation methods;

(iii). If at all the shadow prices are obtained and if the project evaluation methods are used to calculate and recoup the fixed cost component, obviously the rates that the consumers are expected to pay during each instalment will shoot up. Water being a necessity it is undesirable to charge so exorbitantly, especially in an underdeveloped country where the capacity to pay of a fairly large section of people is very much limited;

(iv). The state may not desire to impose such a high rate due to socio-political reasons.

Instead a dynamic model is proposed with the following attractive features to recover the fixed cost from the consumers. As years pass by, the number of consumers in any water supply system usually increases until it reaches its full capacity. Then the fixed cost component is shared by a larger number of consumers thereby reducing the burden of price. Thus the rates are also likely to reduce, so long as additional investment does not take place. The actual real cost of investment will always be recovered because the inflationary component is also part of the rates for this model.

The dynamic recovery formula is discussed below. Let I_0 be the initial investment and 't' be the life of plant and machinery; 'r' be the rate of recovery such that the full cost is recovered at the end of its life span; n_t be the number of consumers in t th year and x_t be the appropriate price index with the year of investment of fixed cost as the base. Let the first year of recoupment of fixed cost be I_1 and 'n_1' be the total consumers in the first year. Then the component of fixed cost to be recouped from the consumers in the first year and the rate charged should be the following.

$$P_f^1 = I_1/n_1, \quad \text{where} \quad I_1 = r\, I_0$$

where P_f^1 be the component of price to be charged during first year for the fixed capital. Suppose that inflation during the first period is x_1 then the rate at which the fixed capital is to be recouped during the second period is given by:

$$P_f^2 = I_2 / n2 \; ; \text{ where } I_2 = (I_0 - I_1)(r + x_1)$$

Similarly for the third year.

$$P_f^3 = I_3 / n_3 \; ; \text{ where } I_3 = (I_0 - I_2)(r + x_2) \quad \text{etc.}$$

For the t th year ;

$$P_f^t = I_t / n_t \; ; \text{ where } I_t = (I_0 - I_{t-1})(r + x_{t-1})$$

The general formula is given by :

$$P_f^i = I_i / n_i \qquad \text{---------- 6.1}$$

where $I_i = r\, I_0$; $i = 1$ and

$$= (I_0 - I_{i-1})(r + x_{i-1}) \; ; \qquad \text{----------- 6.2}$$

$$i \# 1, \quad i = 2 \ldots\ldots\ldots t$$

The application of the formula is discussed below.

6.1.3. Empirical Estimation:

Since plant I has already crossed its life span, the fixed cost of only plant II is to be recovered. It consist of plant and machinery, conveyance main, the distribution system and the dam constructed for the storage of water.

Fixed investments have been made by the KWA in respect of plant II and the dam in three different periods. The first investment [1] of plant II completed in 1977, followed by the second investment by capacity addition during 1986. The storage dam was completed during 1983. The life expectancy of the plant and the dam are fifty years, based on the general engineering expectations. For the purpose of accommodating inflation into the pricing formula three separate weighted indices of prices constructed. The three indices have been constructed separately because of the differences in the constituent components of capital investments in their respective periods. For the construction of index, wholesale prices of following materials are considered, basic metals, alloys and metal products, and machinery and machine tools. Of which the first one can take care of all the construction materials that are used for the construction of plant and building, filter chambers etc. and that of the dam. The second component takes care of components like pipes, steel and other allied products and the third of electrical equipments that have gone into the fixed capital. The weights are assigned according to the share of each component in the total cost.

Using the model for the recovery of fixed cost, a price for 1992 is obtained for all the three investments. The details of the computation are given :

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[1]. Though the treatment plant was commissioned other works such as laying of trunk mains and distribution lines were pending for completion. Since the investment could be completed only during 1977, that year has been taken as the year of completion. The component I_0 is inclusive of the interest payments that the KWA has to pay to the Life Insurance Corporation of India for the financial assistance, extended for the implementation of the project.

I_{92} (Plant II, 1977) = Rs. 2211672.77

I_{92} (Plant II, 1986) = Rs. 1285693.49

I_{92} (Dam, 1983) = Rs. 2168700.09

Total I_{92} = 2211672.77 + 1285693.49 + 2168700.09 = Rs. 5666066.35

Total number of consumers during 1992 is 80782.

n_{92} = 80782

P_f^{92} = 5666066.35/80782/12 = Rs. 5.85 / month.

During 1992-93, altogether an amount of Rs. 5666066.35 was to be recouped from the consumers. During the year it is estimated that there are 80782 consumers in TWSS. The price per consumer per month is Rs. 5.85.

Section II

6.2. Pricing Models:

Now let us examine the recovery of second part of the cost, variable cost. The break even cost is calculated from the cost function given in chapter iv. The estimated cost function in chapter iv is,

$$\log AVC = 3.039 + 0.00004\ o_t$$

Evaluating the AVC using capacity output of plant I and II, that is 39420 million litres per year, the AVC = Rs. 1.03 per Kiloliter (K.l). This figure is used for the calculation of rate structure given below.

The price should be set to recover the break even cost in such a way that the consumers from the higher income group should have a higher price. This distribution of costs resembles the theory of cross subsidy discussed by Faulhaber (1975) in the context of multi product pricing in a game theoretic framework. The formulation of rate structure with cross subsidy is examined using two alternative models.

6.2.1 Model I: Cost Determined Rates:

This model considers only the cost of production of water. The cost determined prices with cross subsidy between consumers require the calculation of stand alone cost (SAC) of each group. The concept was introduced by Faulhaber (1975) in a different context of pricing in the theory of coalition. In this model the three broad groups proxied by the type of construction are considered for the allocation of stand alone cost. They are pucca, semi pucca and katcha households. Obviously pucca households belong to the highest income group and katcha to the lowest income class.

The stand alone cost of each group is defined as follows. Let $(SAC)_p$, $(SAC)_s$ and $(SAC)_k$ be the stand alone costs of pucca, semi pucca and katcha households respectively. AVC be the break even average variable cost and O_p , O_s, and O_k be amount consumed by pucca, semi pucca, and katcha households[2]. The stand alone cost of each category of consumers is given by;

$(SAC)_p$ = Avc * O_p = 1.03 * 6455.08 = 6649.56 ------- 6.3

$(SAC)_s$ = Avc * O_s = 1.03 * 2276.34 = 2344.64. ---------6.4

$(SAC)_k$ = Avc * O_k = 1.03 * 470.67 = 484.80. ---------6.5

In order to fix the prices with cross subsidy the stand alone cost need to be reassigned from one group to another which depends on the welfare function of the state.

Suppose the state decide to cross subsidise completely the poorest income group, the katcha households, and recover the additional cost from the highest income group, pucca households, leaving the semi pucca households.

The new stand alone cost under `this welfare function' with cross subsidy is :

$(SAC)_p^1$ = $(SAC)_p$ + $(SAC)_k$ = 7134.36,

$(SAC)_s$ = 2344.64, and

$(SAC)_k$ = 0,

---

[2] . The derivation of the average per capita consumption and the respective frequencies of pucca semi pucca and katcha households are from the survey data. As this is a sample survey with probability proportionate to population, an extension of this can be used to estimate the true stand alone costs of the respective groups in the population, which too may not differ much from the estimate. The tests conducted also confirm that the samples are distributed normally with probability proportionate to population.

Where $(SAC)_p^1$ is the sum of the stand alone costs of pucca and katcha households.

In this case the rate structure will be as follows:

$P_p = (SAC)_p^1 / O_p = 7134 / 6455 = R\ 1.07 / K.1$ ------6.6

$P_s = (SAC)_s / O_s = 2344.64 / 2276 = R\ 1.03 / K.1$ -------6.7

$P_k = R\ 0.00 / k.1$ -------6.8

Thus the katcha dwellers who are the poorest among the consumers can be fully subsidised with a small increment in the prices of pucca households without considerable increase in their rates.

The above model has several limitations. It has no incentive for economizing consumption, especially among katcha households when it is a free good. The income groups are not flexible. Therefore we propose a general model for deciding the rate structure.

6.2.2 Model II: A General Model for Rate Structure:

This generalised model is a variant of Third Best Pricing rule propounded by Danielsen, Kamerschen and Keenan (1990; hereafter D-K-K). The theoretical description of this pricing rule is given in chapter II. The three steps involved in the rate determination of this model are: (1) the determination of appropriate number of slabs; (2) assignment of revenue responsibility on each slab; and (3) the determination of rate structure from the revenue allocation with cross subsidy. Let us examine the details of these steps.

The first step is the fixation of slabs. The KWA has only four slabs for domestic consumers at present. They are: slab 1 up to 10 (K.l); slab 2, 10 K.l to 30 K.l; slab 3, 30 K.l to 50 K.l; and slab 4, > 50 K.l. However a seven slab system is used for our analysis in order to bring in more flexibility in the rates. They are: slab 1, up to 10 K.l; slab 2, 10 - 15 K.l; slab 3, 15-20 K.l.; Slab 4, 20-25 K.l; slab 5, 25-30 K.l; slab 6, 30 - 35 K.l; and slab 7 > 35 K.l.

The above slab structure is designed to accommodate all income class and also to bring in an economic incentive for reduced consumption. One can also use other variations of this slab.

The next step is the assignment of revenue responsibility among given classes of consumers. The need for such a class revenue responsibility according to D-K-K is that, if the regulators are omniscient, they could set optimal second best rates at the outset and ignore revenue responsibility by each customer class, which means that neither the capacity of the consumers to pay nor their welfare is considered or on the other hand the setting of prices in like manner is only from the producers point of view. In order to avoid this, they segregate class revenue responsibilities. They also put forth the condition that the overall revenue should be able to meet the total cost of the firm. Unfortunately the authors do not suggest a method for revenue allocation among the different classes.

The following method is proposed in the model for revenue allocation across different slabs. The details of that revenue allocation and rate determination are given below.

The basis of revenue allocation can be based on the consumption of each class or their income, or both. Since the income of each household is not known the mean floor area per household has been taken as a proxy. First the total revenue at break even has been distributed according to the share of floor area to each class. The resulting revenue allocation is divided by its actual total consumption. The rates obtained show that the lower income class (Table 6.1). This may be due to the relatively lower consumption of the lower income groups.

Table 6.1

Income Weighted Rate Structure

Size class (K. litres)	Mean Floor Area per Household (Sq. feet)	Share by size	Total Consumption (K. litres)	Total Revenue (Rs.)	Revenue Allocation (Rs.)	RATES
1	2	3	4	5	6	7
1-10	834.62	0.0995	244.00		943.50	3.87
10-15	878.16	0.1047	2220.22		992.73	0.45
15-20	1040.16	0.1240	2210.89		1175.86	0.53
20-25	1077.38	0.1285	1367.02		1217.94	0.89
25-30	1411.00	0.1683	1191.32		1595.09	1.34
30-35	1419.23	0.1693	841.25		1604.39	1.91
above 35	1724.44	0.2057	1128.16		1949.43	1.73
TOTAL	8384.99	1	9202.86	9478.95	9478.95	1.03

Notes: Details of the calculations are given below,
Col.3 = col.2 / 8384.99
Col.6 = col.3 * 9478.95
Col.7 = col.6 / col.4

Source: Sample survey

In order to overcome this problem, the share of consumption has been taken as the basis for revenue allocation (Table 6.2). This shows that the lowest slab has the highest rate and differences vary substantially among the slabs. Therefore both income and consumption have been taken in the revenue allocation.

Table 6.2

Consumption Weighted Rate Structure

size class Consumption Range	Mean(h.h) Consumption (K.Litres)	share of Consumption	Total cost VALUE (Rs.)	revenue Allocation (Rs.)	Total Consumption (K.litres)	Rates (Rs.)
1	2	3	4	5	6	7
1-10	9.3846	0.06		545.58	244.00	2.24
10-15	12.0012	0.07		697.70	2220.22	0.31
15-20	17.4086	0.11		1012.06	2210.89	0.46
20-25	22.4102	0.14		1302.83	1367.02	0.95
25-30	27.705	0.17		1610.65	1191.32	1.35
30-35	32.3558	0.20		1881.02	841.25	2.24
above 35	41.7837	0.26		2429.12	1128.16	2.15
TOTAL	163.0491	1	9478.947551	9478.95	9202.86	1.03

Notes: Detail of the calculations are given below.
Col 2 = col 1/total col 1
Col 4 = col 2 * col 3
Col 6 = col 4/ col 5

Source: Survey data

More specifically income weighted consumption is used for revenue allocation. The allocation is done in the following way.

Table - 6.3

Income Consumption Weighted Rate Structure

size class Consumption Range	Frequency	Mean Floor Area per Household (sq. feet)	Share of Floor Area	Total Consumption (k.l)	Total Revenue (Rs)	Weighted Consumption	Aggregate Price	Revenue Allocated (Rs)	Rates per Kiloliter (Rs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1-10	26	834.62	0.0995	244.10		24.29		179.63	0.74
10-15	185	878.16	0.1047	2220.2		232.52		1719.80	0.77
15-20	127	1040.16	0.1240	2210.89		274.26		2028.49	0.92
20-25	61	1077.38	0.1285	1367.02		175.65		1299.12	0.95
25-30	43	1411.00	0.1683	1191.3		200.47		1482.72	1.24
30-35	26	1419.23	0.1693	841.25		142.39		1053.14	1.25
above 35	27	1724.44	0.2057	1128.16		232.02		1716.04	1.52
TOTAL	495	947.95	1	9202.86	9478.95	281.60	7.396	9478.95	

Notes: Details of the calculations are given below:

Col. 6 = 1.03 * Col. 5
Col. 7 = Col. 4 * Col. 5
Col. 8 = Total of Col. 6 / total of Col. 7
Col. 9 = 7.4 * Col. 7
Col.10 = Col. 9 / Col. 5

Source: Sample survey.

First the aggregate price is arrived at by dividing the total revenue at break even by the sum of rescaled consumption. The aggregate price is then multiplied by slab wise weighted consumption for revenue allocation. The revenue allocation, obtained for each class is then divided by their corresponding unscaled total consumption to obtain the rate structure.

The rate structure thus obtained satisfies the cross subsidy, break even condition and is monotonically increasing with the consumption. The rate structure shows that the first four slabs have prices below, and the rest three slabs above the break even prices.

The price for each slab is given by simply adding the component due to average fixed cost to the above rate structure. Though the model is specifically meant for household consumers, it can be generalised to include all non-household consumers.

Section III

3.1. Summary:

In this chapter a pricing model for the water supply system in Kerala has been developed. The price structure is based on the two part tariff system which satisfy the condition of:

$$P = AC = AFC + AVC.$$

In the first part a dynamic model of recoupment of the fixed cost is attempted, so that there is neither any loss for the investors nor for the consumers during the life span of the project. In the second part, the pricing of the variable cost at break even is examined with two alternative models. The second model incorporates cross subsidy which is easy to operationalise.

3.2. Limitations of the Pricing Models :

One possible criticism that can be raised against these pricing models is the inconsistencies in the assumption of optimum capacity utilization for production, while the plant has a design capacity to cater to the prospective population of thirty year period assumed by the engineers. But since the cost function is exponential, during initial stages of production the variable cost shall be lower, thereby the break even shall be attained at a lower average variable cost itself. Further when the model becomes operational, some of the consumers may tend to consume lesser quantities and thereby reducing the total revenue of the firm. Then a revised reallocation of the class revenue responsibilities may be needed in the long run.

Chapter VII

SUMMARY AND CONCLUSIONS

The role of self financing Public Utilities has become very important, especially in the present context, since the governments both in the centre and in the states are finding difficult to subsidise these services. In this context, the pricing of public utilities like electricity, water etc. becomes important. The present study has attempted to develop a model for the pricing of drinking water taking the Trivandrum Water Supply System as a case study. But the development of an appropriate pricing policy requires an understanding of its cost and demand functions.

In the analysis of cost functions first the plants installed at different periods were analysed separately to highlight their respective technical advantages and disadvantages. Then an aggregate analysis of the cost functions of both the plants combined has been attempted. Separate cost functions for plant I and Plant II show that the oldest plant established in 1933 is still cheaper if produced at capacity output. For the calculation of prices at break even the aggregate cost function has been used. It is observed that while the plant wise cost functions are linear, the aggregate function turns out to be an exponential function.

The effects of socio-economic factors and the household composition on water demand have been examined using the sample data collected from 555 consumers. The effect of household size on consumption is examined first by constructing an adult equivalent scale. The results show that the equivalent scale has unity for adult female, 0.47 for adult male, 0.11 for children between the age of five and fifteen, and 0.06 for a child below five years of age. The socio-economic factors affecting the water demand after eliminating the household effect is then examined using multiple regression analysis. The regression results show that education, floor area, number of taps per floor area, frequency of house cleaning, consumer durables and number of flush per bath room influence the per capita consumption of water.

While formulating the model for pricing for the water supply system, a specific model suitable to Kerala has been developed. The price structure is based on the two part tariff system which satisfy the following condition:

$$P = AC = AFC + AVC$$

where P stands for price; AC, average cost of production; AFC, its average fixed cost component; and AVC its variable cost.

In the first part, a dynamic model of recoupment of fixed cost during the life span of the project is attempted, so that there is any loss neither for the government nor for the consumers. In the second part, the pricing of the variable cost at break even is examined with two alternative models. The second model incorporates cross subsidy which is easy to operationalise.

From the above study the following observations can be made.

(1) It is imperative to make a thorough study of all the plants in the Kerala water Authority, if so probably the Authority could save a lot of it's operation and maintenance expenditure, as the analysis of one of the system itself gives a lot of insight as to how the system requires revamping.

(2) The success of any pricing policy crucially depends on the accountability of water consumed at regular intervals. It is reliably learned from the KWA sources that almost 60 per cent of the meters installed are faulty. As a result a substantial quantity of water consumed is not accounted, which may encourage the consumers to misuse it. In this context the KWA should make consumers responsible for the proper maintenance of the meters.

(3) The efficiency of TWSS can be improved in several ways. Plant I should be operated at the optimum capacity level. The leakages in plant II should be rectified for maximum capacity use. In plant I a re-deployment of labour force is required for maximum efficiency.

(4) Any new system should be introduced only after a thorough cost benefit analysis.

(5) Leak detection studies should be conducted for the water systems and correction methods should be immediately implemented.

Suggestions for Further Research:

The present study can be extended to several directions. A rate structure with revenue allocation on the basis of predicted demand can be examined. The system of peak load pricing or constrained linear programming methods can also be explored for the determination of pricing with cross subsidy. The application of the present methodology for other utilities needs further investigation.

APPENDIX - I

SURVEY ON THE DEMAND FOR DRINKING WATER

Block I - Identification: Sample no.

1. Trivandrum corporation House / ward no.
2. Name of the head Name of informant
3. Location Street
4. No. Of members Adult male Adult female
   Children < 5 years 5 to 15 years.
5. Occupation of the head (describe)
6. Other employed (describe and nos)
7. The highest education obtained by the member of the household
8. What is the educational status of house wife

Block II - Housing conditions.

1. ownership - Owned (1) Rented (2) Leased in (3)
2. Type of structure Pucca (1) Semi Pucca (2) Katcha (3)
3. Approximate floor area of the building (Square feet)
4. Number of taps (Nos). Number of bath rooms/ toilets (nos)
5. Whether connected with flush Yes (1) No (2)
6. If yes capacity < 5 liters (1) >5 and <8.5 liters (2) all>8.5 (3)
7. No of times used in an average per day (nos)
8. How many times do the family members take bath (Pipe water only)
9. How many times do cook daily (1), Twice daily (2), Thrice (3),
10. How do the clothes are washed - Household members (1)/ Servant (2)/Dhobi (3)/ Washing machine (4)/others (5)
11. Do you wash clothes: daily (1)/Two days (2)/ Three days(3) / weekly(4)
12. Do you clean the house using pipe water : daily (1)/ Two days (2)/ 3 days (3)/ weekly(4)/ others(5)/ No cleaning (6)
13. How much quantity of water do you use for gardening : With lawn liters /day, Without lawn (liters/ day), No of coconut trees (own only) Land owned within city

Block - III - Household equipments possessed.

1. Do you have washing machine : Yes(1) No (2)
2. Do you have geeyser Yes (1) No(2)
3. Do you have dishwashers Yes (1) No (2)
4. Do you have pressure cookers Yes (1) No (2)
5. Do you have vacuum cleaners Yes (1) No (2) Has it been used regularly Yes(1) No (2) How many times in a week (Nos)
6. Do you have a vehicle - Yes(1) No(2) , If yes Car(1)/ Two wheeler(2)/ Other four wheelers (3)/ Others (4)
7. Do you wash the vehicle - Yes (1) No (2)
8. If yes intermittence - Days ( ) & Quantity of water used/wash

Block IV - Animal Statistics:

1. Do you have any animals - Yes (1) No (2)
2. How much water do you use (including washing) for animals

Block V - Other uses:

1. Is there an over head tank / sump in your house
2. Do you get water regularly - continuously Yes(1) No(2) With adequate pressure Yes(1) No(2)
3. If breaks how much time and in which season
4. If continuous supply is provided will you use more water Yes (1) No (2)
5. Do you purify pipe water - Yes(1) No(2)
6. If yes, how - Boil (1)/ Household Filters (2)/ Others(3).
7. What is the usual monthly water charge do you pay Rs 0.00

Block VI - Commercial undertakings:

1. Type of establishment :- Shops(1)/ Hotels(2)/ Industry(3)/ School(4)/ Public office(5)/ Others(specify)(6).

2. Monthly water charge paid Rs 0.00

3. Number of labourers working (Nos)

4. Number of visitors - (In the case of restaurants / eating places (Nos).

Remarks / Observations:

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